SCIENTIFIC AMERICAN SUPPLEMENT

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LITTLE DANGER WHEN IN A WOOD
DISTANCE FROM STORM IT TAKES FIVE SECONDS FOR THE NOISE OF THUNDER TO TRAVEL ONE MILE
DIAGRAM SHOWING NETWORK SYSTEM NOW IN USE AT WESTMINSTER ABBEY
EARTH
GIVE A WIDE BERTH TO TELEGRAPH POSTS DURING A VIOLENT STORM, AND NEVER USE THE TELEPHONE
COPPER WIRE CONNECTED WITH ALL THE LIGHTNING CONDUCTORS ON A BUILDING IS SURROUNDED BY CHARCOAL AND SOLDERED FIRMLY IN "EARTH"
TUBE CONNECTED WITH WATER TANK TO KEEP THE EARTH MOIST
IF CAUGHT ON OPEN GROUND
LIE FLAT
GAS-MAIN

From the *Illustrated London News*.

How to get struck by lightning, and how not to.

LIGHTNING AND ITS DANGERS.—[See page 102.]

Thermo-Electric Measurements of Stellar Radiation*

By the Aid of a New Type of Thermo-Electric Junction

By A. H. Pfund

In the year 1901 Prof. E. F. Nichols published an account of his radiometric determinations of the "Heat of the Stars."[1] He was, in fact, the first to show that such extremely minute quantities of radiant energy could not only be detected but could be measured to a very fair degree of accuracy. In spite of the encouraging prospects which this work held forth, nothing further was done for more than a decade. Within the past year or two the writer has had occasion to develop a sensitive thermo-electric junction which gave promise of yielding useful results when applied to the measurement of stellar radiation. As the opportunity presented itself of using the 30-inch Keeler Memorial Reflector at the Allegheny Observatory, the apparatus was carried to Pittsburgh and tried out. The work was merely of a preliminary character and its object was, mainly, to learn of the difficulties which would have to be overcome in order that useful results might be obtained. In spite of the imperfections of the apparatus and the unavoidably great distance (more than 40 feet) between the thermal junction and the galvanometer, very reliable deflections considerably larger than those of Nichols were obtained. The apparatus had to be so designed that the thermal junction could be slipped into the eye-piece end of the telescope, from which wires could be led to the galvanometer mounted in another part of the building. The actual arrangement used is shown in Fig. 1, where *A* is the brass tube which slips into the telescope; *B* is the capsule containing the thermal junctions which are mounted at *C*. The front and rear openings of the capsule are closed by plates of fluorite (*F*) and glass (*G*), respectively. The eye-piece (*E*) enables the observer to see the junctions and the star image. The charcoal evacuator (*H*) and the binding-posts (*P*) are attached as indicated.

Two types of thermal junctions were made, but unfortunately the one of inferior design had to be used, as the other was of too high a resistance to yield the desired sensibility. The type used is shown in Fig. 2, where *A* and *B* are the blackened disks upon either of which the star image could be projected. The filaments 1 and 2′ were of a bismuth and tin alloy, and those marked 1′ and 2 were of a bismuth and antimony alloy. As is obvious from the figure, the filaments 1, 2, 1 and 1′, 2′, 1′ form two separate compensating junctions of which the blackened disks *A* and *B* form the receiving surfaces. Each disk is composed of two parts which overlap slightly but do not make electrical contact. A compensating system is necessary in order that any stray radiation from a warm mass of water vapor or carbon dioxide might fall upon both junctions and thus produce no resultant galvanometer deflection; while the radiation from the star, falling on but one junction, would alone be responsible for the effects observed. The area of each disk was 1.1 square millimeters, and the separation of their centers was 4 millimeters. As this separation was unnecessarily large, a second type of junction, shown in Fig. 3, was constructed. Here the disks were separated by a clear space of 0.5 millimeter. As better compensation is to be obtained by the use of this type of junction, it is to be recommended for future work. The actual method of making these delicate junctions has been described elsewhere.[2]

The evacuator (*H*), Fig. 1, is simply a highly exhausted vacuum tube containing cocoanut charcoal as one electrode. Whenever it becomes necessary to remove the small amount of gas which has leaked into the capsule containing the thermal junctions, it is only necessary to establish an electrical discharge by means of a small transformer suitably connected to the terminals of the tube. This process produces so high a vacuum that the sensibility of the thermal junction increases at least five times over that which it had when surrounded by air at atmospheric pressure, and in addition to its portability, it has the further advantage over Dewar's process that the charcoal retains the gases once absorbed.

The D'Arsonval galvanometer used was designed by Dr. F. Wenner and was made in the instrument shops of the Bureau of Standards. On open circuit the complete period of the suspended system was 11 seconds. Under actual working conditions the voltage-sensibility with the scale at 5 meters was about 6×10^{-9} volts. Although the mirror, which was 6 millimeters in diameter, ought to have shown sufficient resolving power to give a sharp image at this scale distance, it was found that imperfections of figure in the mirror made it impossible to read deflections closer than fifths of a millimeter. The galvanometer was mounted on a stone pier built up from the ground and free from contact with the floor, thus giving great stability to the instrument.

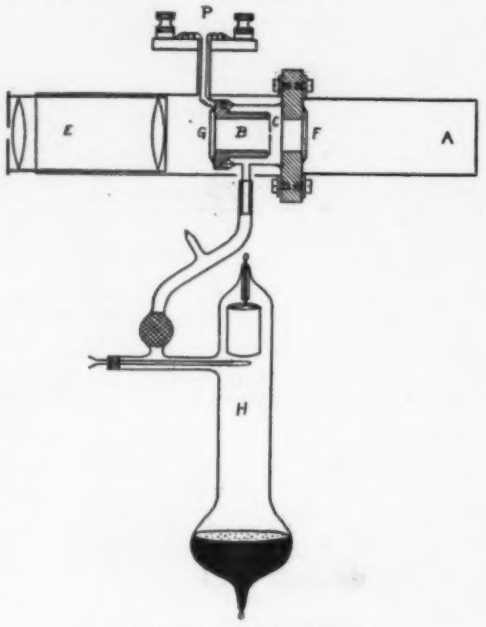


Fig. 1.—General arrangement.

A test of the sensibility of the apparatus was carried out by exposing one of the junctions of the thermal couple to a standard Hefner lamp at a distance of 5 meters. The resultant deflection was 96 millimeters which corresponds to a deflection of 2,400 millimeters with the Hefner lamp at 1 meter. The 30-inch telescope is of the Cassegrain type, and, as a consequence, a central disk 8 inches in diameter is rendered inoperative by the secondary mirror. Taking this into consideration and neglecting atmospheric absorption, it appears that, if the image of the Hefner flame were focused on the disk of the thermal couple by means of this telescope, a deflection of 1 millimeter would result if the lamp were removed to a distance of about 8 miles.

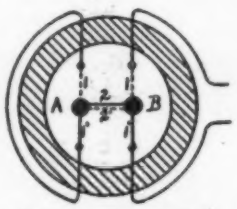


Fig. 2.—The thermal junction.

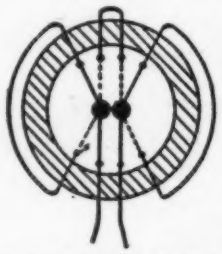


Fig. 3.—Thermal junction with closed disks.

The method of measuring the total radiation of a star was briefly as follows: The thermal junction mounting was rotated axially until the line connecting the two blackened disks lay in the direction of the telescope's motion in declination, thus enabling the observer at the telescope to shift the star image from one disk to the other simply by turning a handle that slightly changed the pointing in declination. This act of shifting the star image required from 1 to 1.5 seconds. To begin with, the star image was kept on one disk and when the observer at the galvanometer was ready, he whistled once, whereupon the observer at the telescope also whistled once and immediately shifted the star image to the other disk. Twenty seconds after returning the first signal the observer at the telescope whistled twice in rapid succession, and the observer at the galvanometer recorded the deflection. The next deflection was obtained in a similar manner by shifting the star image in the opposite direction. This prolongation from 5.5 seconds, the half period of the galvanometer on open circuit, to 20 seconds, was due largely to electromagnetic damping occasioned by short-circuiting the galvanometer through the thermal couple, which had a comparatively low resistance. As the galvanometer was not specially constructed for this work, the above conditions were unavoidable. In spite of this rather long time of exposure, the deflections were so constant that, no doubt, a considerably longer exposure might have been possible without sacrificing accuracy of result.

On the evening of September 22nd, 1913, the final series of results were obtained. This was the only evening between the time that the apparatus was ready and the time set for the writer's departure for Baltimore, that the sky was sufficiently clear for observations, and on that evening conditions were favorable only until about 11 P. M. During this series of observations, Dr. Grondahl carried out the manipulations at the telescope while Mr. Zaccheus Daniel and the writer observed the galvanometer deflections. After ten or more deflections had been noted, Dr. Grondahl and the writer exchanged places, Mr. Daniel continuing in observing the deflections. The results obtained are here given:

Source.	Deflection, Millimeters.	Visual Magnitude.	Remarks.
Vega	7.5	0.19	Clear sky, no wind.
Jupiter	3.0	−2.0	Clear sky, no wind.
Altair	2.0	0.96	Hazy sky, no wind.

In every case the flections followed so definitely when the signal was given that not even a skeptic could have doubted the reality of the effect. The galvanometer zero was remarkably steady, and in every case was it possible to predict the direction and approximate magnitude of the deflection, after having observed the first of a given series. The deflections were so consistent that among the ten or more readings taken on Vega, the difference between the largest and smallest was less than 1 millimeter. Considering the crudity of the signaling and timing devices, such differences in reading are not surprising. In the case of Jupiter it was found impossible to receive the entire image of the planet on the blackened disk of the thermal junction. The equivalent focal length of the reflector as used was about 60 feet; as a result, the image of Jupiter was 3.4 millimeters in diameter and 8.4 square millimeters in area. Since the blackened disk had an area of 1.1 square millimeters, less than one seventh of the total radiation was received. If the entire image of Jupiter could have been concentrated on the thermal junction a deflection of 23 millimeters would have been obtained. It goes without saying that the disk of the thermal junction was amply large to receive wholly the images of Vega and Altair.

In order to test whether the necessary slight motion of the telescope in declination might affect the observed deflection, the star was thrown out of the field, and the telescope was given the former slight motion several times at the usual signals. No resultant effect was observed.

A comparison of the preceding results with those of Nichols is not easy. Nichols's radiometer was carefully shielded from draughts and was mounted in a room into which the star image was projected. In the present work no protection was given the thermal junctions, lead wires or galvanometer. Furthermore, the thermal junctions were mounted in the open dome of the observatory where air draughts were unavoidable and where the temperature was several degrees lower than in the room containing the galvanometer. That reliable results were obtained even under these conditions is due to the excellence of compensation throughout the system. In the comparison of results such differences as areas of receiving surface, size of reflector, nature of standard comparison source, etc., increase the complication. A rough calculation shows that if Nichols had used the 30-inch reflector with his best radiometer (used in 1900) and had also carried out "double deflections," he would have obtained from Vega a deflection of 2.26 millimeters, whereas the writer obtained 7.5 millimeters. Under the actual conditions of his experiments which involved the use of a 24-inch reflector, Nichols obtained a deflection of 0.51 millimeter from Vega.

As to the desirability of developing such apparatus as this but little need be said, for it is evident that, by means of a radiometric device, entirely new problems in Astrophysics may be attacked. As for the thermal junction, its development for such work has only begun. That thermal junctions of still higher sensitiveness may be made is more than probable; and it is certain that, thanks to the labors of Abbott and Paschen, Thomson galvanometers, easily ten times as sensitive as the D'Arsonval used by the writer, may be constructed and used with success. Such improved apparatus, used in conjunction with one of the largest reflectors, would make possible the study of stars of even the fourth magnitude.

* From the Publications of the Allegheny Observatory of the University of Pittsburgh.

[1] *Astrophysical Journal*, 13, 101, 1901.

[2] *Physikalische Zeitschrift*, 13, 870, 1912.

Battleships and Submarine Attack

In view of the widespread war in Europe, that will undoubtedly involve most of the great navies of the world, a paper recently read by Sir John Biles before the Institute of Naval Architects at Newcastle-on-Tyne on "Battleships and Submarine Attack" has proven most pertinent and opportune; and this paper, together with a letter written to the *Times* by Sir Percy Scott on the submarine menace, is made the subject of an editorial discussion in the *Engineer*, London, from which the following extracts are taken:

"Sir John Biles's paper briefly raised four main points, which, slightly transposed, were: whether the submarine menace was sufficient to justify armoring the under-water portions of a ship to a much greater extent than is done at present, and, if so, whether 4-inch armor would form sufficient protection; or was the menace sufficient to justify the construction of smaller and slower battleships carrying six guns only instead of eight or ten, and would armor be of sufficient value to justify a modification in the form of ship, which, although facilitating the manufacture of the armor, would offer greater resistance than the ordinary form? In the course of the subsequent discussion, answers to these queries were afforded by the statesman, the naval officer, and the ship constructor to a varying degree. The fourth question was immediately shattered by Mr. Charles Ellis, who expressed the opinion that just as armor plate makers had already been forced to provide shapes which were considered impossible only a few years ago, so they would be able to furnish in future armor of any shape likely to be required. Lord Brassey was disinclined to overlook the arguments in favor of the same total armament carried in more and smaller vessels, a view that Sir Philip Watts contradicted in his remarks. He alone categorically answered all the four questions propounded, and his views are of great interest, as he stated plainly that up to the present time the submarine menace had not been considered of sufficient importance to justify armor protection on the bottom of a ship; but he thought that 4-inch armor, if supported by suitable internal subdivision, would afford sufficient protection against torpedoes. Sir Reginald Custance confined himself to the war value of the Whitehead torpedo, and, basing nearly all his remarks on the experience of the Russo-Japanese war, regarded the torpedo as a very inferior weapon to the gun, and one on which too much reliance should not be placed. Prof. Hovgaard's contribution to the discussion dealt mainly with the constructional possibilities in protecting a vessel's bottom, and pointed out that to do so effectually against external explosions a resistance greater than that afforded by the inertia of the water must be provided. For a big charge and a depth of 20 feet this would seem almost impossible.

"It is also curious that this sudden phase of thought over the dangers to a vessel of a torpedo striking her should have led to so much discussion without anyone having pointed out that it is quite immaterial whether the torpedo is fired from a surface craft or a submarine, and that the danger from the former is also a very serious matter indeed with modern long-range torpedoes, and one in which, as far as destroyers are concerned, there is already a considerable amount of war experience. Certainly, hitherto the whole argument has had nothing to do with craft other than submarines, but at the back of the whole question lies the capability of the structure of the modern battleship to withstand torpedo attack. The matter has been debated every year since the introduction of the automobile torpedo nearly forty years ago. Put on 4-inch armor and increase the sub-division—Sir Philip Watts suggested even thicker armor if necessary—and what will be the result; only to increase the diameter, and with it the bursting charge, of the torpedo? What has been the history of the gun? Till Sir Percy Scott led the way in target practice it is doubtful if the percentage of hits with it in war time would have been any better than it was with the torpedo in the Russo-Japanese war. In fact, in the Spanish-American war it was vastly less. The experience in the Sea of Japan with 16-inch and 18-inch torpedoes was sufficient seriously to affect the internal protection and sub-division of the entire Dreadnought type, and this was before the introduction of the 21-inch torpedo with its hot air attachment and gyroscopic control; and what Scott did for the accuracy of the gun, these have accomplished for the torpedo. Many officers seem to think that the menace of destroyers is a vastly greater deterrent than that of submarines which are relatively slow, and there is no doubt that with the range and accuracy of its existing weapons the surface boat is a very formidable antagonist to the big ship. It is, however, a visible foe; but, on the other hand, it is a habitable one. These conditions are largely reversed in the case of the submarine, which by no means possesses the sea-keeping capabilities of the destroyer. Why, then, was the risk of a successful destroyer attack, i. e., if a torpedo got home, treated so lightly? Why has the destroyer programme been reduced in England and France and the submarine flotilla increased? The fact is that warship design is in a state of flux, and even among naval officers there is a very wide diversity of opinion as to the relative value of various types.

"The limitations to increase of size in torpedoes are less than in the case of artillery, and consequently a more dangerous projectile can be introduced with relatively small difficulty in order to maintain the superiority of the attack. To this the only real answer that can be made is a radical change of type of big ships, rather than the piling on of defensive properties. Effectively to armor the under-water sides of a vessel of the type of the 'King George V' would involve reducing the main waterline belt from 12 inches to 10 inches, and the upper portion of the side from 9 inches to 7 inches and 5 inches, while at the same time it would require an addition to the displacement of some 2,000 tons. That heavier plating will likely be adopted in future is quite another matter. Small thick plates are ill-adapted for withstanding gaseous pressures on account of the difficulty of adequately joining them; the necessity for providing against the intense local percussion caused by a projectile is absent in the case of the torpedo, where the effect is more widely distributed. Actual armor of the present type is, therefore, far less likely to be adopted than steel plates perhaps 1½ inch or 2 inches thick worked in such a fashion that the joints are as remote as possible from one another, and are reinforced on the inside to a much more elaborate extent than is at present provided for above-water work. But when this is done the 21-inch torpedo with its 330-pound charge will become the 24-inch type carrying 500 pounds, and the problem will again require solution. That Sir Percy Scott had this in view when he started to stir up discussion seems very certain; but no one pointed out this fact during the discussion on Prof. Biles's paper. Even with armor and sub-division below water, the attack must remain superior to the defence for the simple reason that all that is necessary is to fire two tubes instead of one. Just as in volley firing it is possible simultaneously to put several 12-inch shells into the space of a tennis court at long ranges, a submarine that can rely on hitting with one tube can almost certainly hit with two, and no defence will withstand such an impact. Naturally, this does not relieve naval architects of the onus of providing all the protection possible to the hull, though obviously the best defence is the destruction of the submarine. How that is to be accomplished is extremely difficult to see, because the type is tending more and more to merge into the sea-going destroyer with submersible capabilities, and of a size and speed that will render it not only much more habitable, but capable of undertaking work at present far beyond its power."

[Sir John Biles's paper in full, with illustrations, will appear in the next issue of the SUPPLEMENT.]

The Geological Action of Man*

By Paul Combes

EVERYTHING in the universe changes more or less rapidly, for change is the essence of phenomena. The surface of the earth has undergone continual alteration since its formation. Most of these changes are due to the physical agencies, which for a long period were the only ones in operation, but the advent of life upon the globe introduced another factor of ever-increasing importance in geological and topographical modifications.

Of all living things, man has produced the most marked effect upon his environment. In order to take account of man's action on the earth's surface, it is necessary to picture the earth as it would appear if the human race had never existed, and to compare that ideal image with the reality. Man acts, successively: as a hunter, upon animal life; as a herdsman, upon both animal and vegetable life; as a farmer, upon vegetable life chiefly; and as a miner and engineer, upon the mineral shell of the earth itself.

Tribes that live by hunting and fishing cause the extinction or diminution of certain animal species. The African elephant is rapidly disappearing. Soon his action upon the tropical flora will cease, and factories and telegraph lines will no longer be in danger from his assaults.

The right whale has taken refuge in Arctic waters and has influenced the distribution of human beings in those regions.

Pastoral peoples, by keeping herds of cattle, sheep, and goats in mountainous regions, destroy the herbage and cause the formation of torrents. The goats and sheep literally "clear" the land on which they browse, and permit the rains to wash away the soil until the rock is laid bare. These animals have ruined Palestine, Greece, and Sicily, transforming these once fertile lands into deserts of bare, sunburned rock.

Agriculture is the most potent factor of topographical changes. See what it has made of the vast marshy forest that was ancient Gaul. The deforestation, clearing, and desiccation of land effected by man since he became an agriculturist, have profoundly modified the distribution, and consequently the very important action, of water on the earth's surface. Intensive culture exhausts the soil by extracting its fertilizing elements, and the fertilizers which man applies in compensation alter the composition of the soil. By burying his dead within the narrow confines of cemeteries, man withdraws from circulation enormous quantities of phosphorus which are thus lost to vegetation. The most fertile lands are transformed into deserts by centuries of cultivation. In this way the rivers have gradually carried down to the sea the elements of fertility of Mesopotamia, Bactriana, and many other lands which once were celebrated for their richness, but now are arid and desolate.

As soon as human communities are formed they act directly upon the surface of the earth. In order to build cities and to establish easy communication between them, man was compelled to execute extensive earth works, to exploit quarries and mines. Still greater alterations of the earth's surface were subsequently produced by the construction of roads, canals, bridges, and aqueducts. The hydraulic engineer has effected equally important changes, straightening the courses of rivers, confining them by dikes, dredging harbors and protecting them by jetties. If the shores of oceans and rivers, thus determined by human action were designated by a special color on a map of the world, their extent would be found surprising.

Man is not content with draining and cultivating swamps and even the beds of lakes—Lake Fucino, in Italy, for example. He conquers vast domains from the sea, as the Dutch have done with their dikes, and as is still being done in the French bays of the Somme and Mont St. Michel. If we had properly studied and comprehended the inspired idea of Commandant Rondaire, we should have created a sea in Algeria and fertilized the Sahara. Man, who has made so many deserts, may perhaps be able to reclaim them. This is being attempted in Algeria by anchoring the sand dunes and sinking artesian wells.

The construction of railways has accelerated the change in the earth's surface, by making cuttings and embankments, filling ravines, spanning rivers, and tunneling through mountains. Here the potency of human action is especially marked. To appreciate this fully, one must have heard the detonations of dynamite and the grinding of drills, and seen the solid granite shattered in the bowels of the mountain.

As the mountain no longer stops the railway train, so the isthmus no longer stops the ship. Suez, Panama, Corinth, Kra, and many other isthmuses have ceased, or will cease, to be what geological agencies made them. Marine fauna migrate from ocean to ocean through the new artificial channels, and islands hitherto neglected become suddenly transformed in consequence of their proximity to the new routes of commerce.

Man will continue to alter the earth's surface in furtherance of his own interests until every line of the map of the world shall bear the impress of human activity. From his advent until his disappearance from the earth man has been and will be the most active, if not the most powerful, of geological agents. Yet his works and his very existence are at the mercy of terrestrial dynamics.

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *Cosmos*.

Iron Ore Output of the World

ACCORDING to an article by C. K. Leith published in the Engineering Supplement of the *London Times*, the annual output of iron ore in the chief producing countries during the latest period (average of 1909, 1910 and 1911) for which the figures are available, was: United States, 50 million tons; Germany, 27; United Kingdom, 15; France, 14; Spain, 8; and Sweden, 5 million tons. Continued heavy production may be expected of the Lake Superior ores, the ores of the Franco-German boundary, the Bilbao ores of Spain, the Cleveland ores of England, and the high-grade magnetites of North Sweden; while increasing quantities of ores may be expected from Sweden and Cuba, and the use of Clinton hæmatites and Adirondack magnetites in the United States will also probably increase. In the near future there will probably become available the Brazilian high-grade hæmatites, Chilean ores, and ore deposits of the western United States, western Canada, India and China.—*Journal of Franklin Institute.*

Development of the Westinghouse Turbine Reduction Gear

Providing a Method for Insuring Uniform Pressure Across the Entire Face of the Teeth of the Pinions

WHILE it was early recognized that the steam turbine was an extremely valuable type of motor for many purposes, it was also soon realized that when it was operated in the most economical manner its speed of rotation was far too great for satisfactory results in some of its most desirable applications. This was especially apparent in the case of marine propulsion, where the economical speed of the turbine is several times greater than that at which the screw propeller can be operated effectively.

Under these conditions it was evidently necessary to provide some form of reduction gearing, and among the gears of this class that have been successfully introduced is the Westinghouse gear, consisting of helical-toothed pinions upon the turbine shaft which operate large gears on the driven shaft, thus effecting the required reduction of speed.

The principal features of this gear are quite simple, but in working out the details of construction interesting problems arose, notably the "floating frame," which carries the driving pinion shaft, and insures uniform pressure across the entire face of the teeth of the pinions.

Not the least interesting feature in the development of this gear is the fact that the fluid pressure employed in the equalizing mechanism furnishes a constant index of the power being transmitted, thus constituting a constant indicating dynamometer.

In a gear to transmit large powers at high speeds it is essential that the tooth pressure should be equally distributed across the entire working face of the gears. To distribute a load of any sort uniformly over several points of support, the most elementary principles of mechanics teach us that we must have recourse to a self-adjusting floating lever, which is known generally as an equalizing bar. To distribute the weight of a locomotive uniformly on the driving wheels, the suspended part rests on equalizing bars, which in turn rest on the journals of the axles. To apply the brakes uniformly to the opposite wheels of a vehicle the braking force must be transmitted through an equalizing bar.

Considering that these propositions are so entirely axiomatic, it is strange that engineers could ever have imagined that in a set of gearing the tooth pressure could be distributed uniformly across the working face of a long slender pinion without some construction that would be more or less the equivalent of an equalizing bar.

The pinion of a reduction gear for use in connection with a marine steam turbine must be long, because a wide face is necessary to transmit the large power required. It must be slender because a comparatively small diameter is demanded in order that, at the high rotative speed, the pitchline velocity may be within reasonable limits. When the teeth of a long slender pinion are loaded uniformly across the working face, the pinion is *twisted*.

For simplicity let us assume that the large gear is cut with straight teeth. If the pinion is to run in rigid bearings, in perfect alignment with the shaft of the large gear, and if the tooth pressure is to be uniform across the working face, it is evident that the teeth of the pinion, instead of being parallel with the axis, should be cut on a slight spiral, so that the twist in the pinion due to the load would just straighten out this spiral, and bring the teeth parallel with the axis. Obviously this would not be a practical solution, as the spiral in the pinion teeth would be correct for one load only. The logical thing to do is to let the pinion teeth assume whatever spiral they will, and to support the bearings so that the axis of the pinion may adjust itself to accommodate the angle of the spiral into which the teeth are twisted. It is well known that a spiral gear will operate satisfactorily in mesh with a straight gear, provided the axes stand at the proper angle with each other.

To illustrate, let Fig. 1 represent a long slender pinion with straight teeth cut accurately in line with the axis *AB*, and which is to mesh with a large gear having straight teeth, and its axis parallel to *AB*. If the tooth pressure is to be uniform across the face of the pinion, the latter will twist, and the teeth will take the position indicated in an exaggerated manner by the dotted line. Then, if the gears are to mesh properly, the end *A* will have to raise slightly, and the end *B* lower slightly so as to bring the dotted line into the position now occupied by the line *AB*, and this is what the floating frame allows to take place. If the pinion were supported in fixed bearings, it could not adjust itself when loaded, and consequently the tooth pressure would be concentrated within a short distance at the driven end of the pinion.

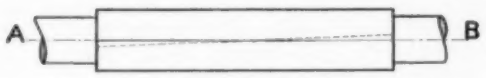


Fig. 1.—Twisting of a long slender pinion.

Again, take the case in which the axes of the gear and pinion are in the same plane, but not adjusted to absolute parallelism. In Fig. 2, let *A* and *B* represent the two ends of the pinion, and *C* and *D* the corresponding ends of the gear. If the center distance between *A* and *C* is less than the center distance between *B* and *D*, then when the teeth are in contact at the end having the shorter center distance, there will be no contact at the other end so long as the axis of the gear and pinion are confined in the same plane. In order to get tooth contact across the entire face of the gear the end *A* of the pinion must lower slightly and the end *B* must raise a little. The floating frame instantly and automatically brings about the required adjustment.

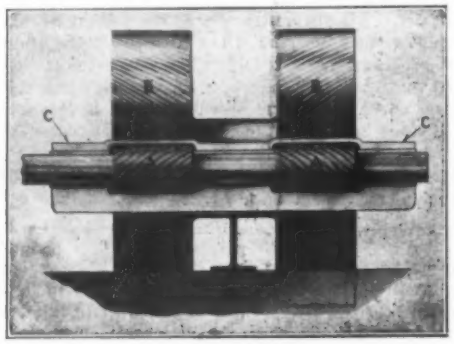


Fig. 3.—Diagram of Westinghouse gear.

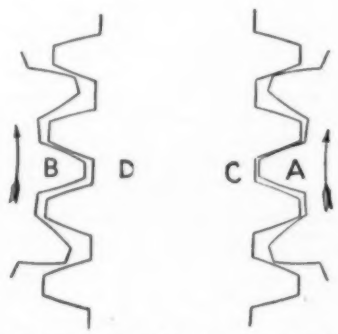


Fig. 2.—Position assumed by teeth at ends of pinion.

Here then are two sets of conditions which require the action of the floating pinion frame to secure proper tooth action, and these conditions are entirely independent of the degree of accuracy with which the teeth may be cut. It is hopeless to expect to get ideal operation with rigid pinion bearings merely by accurate workmanship and fine adjustments, for the reason that the adjustments are variable, and on that account must be effected automatically. For simplicity, we have assumed that the teeth were straight. The same reasoning applies, however, to the helical teeth commonly used on these gears.

The broad idea of the "floating frame" was conceived by the late Rear-Admiral George W. Melville and Mr. John H. Macalpine, who were associated as consulting naval architects and engineers, and who had been for several years engaged in making for Mr. Westinghouse a comprehensive investigation of the application of steam turbines to the propulsion of ships. Mr. Westinghouse, recognizing its importance, and the soundness of the principles on which it was based, undertook to demonstrate its value and practicability.

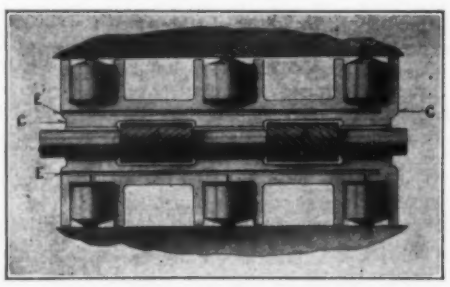


Fig. 5.—Double acting floating frame.

It is not necessary to rehearse the story of the installation of a 6,000 horse-power experimental plant, and the exhaustive tests to which it was subjected. It is sufficient to say that this demonstration convinced engineers that the largest powers could be successfully and efficiently transmitted through properly constructed toothed gearing. It did not, however, convince them that the success of the installation was due to the floating frame. It is only since they have endeavored to dispense with this feature that they have come to recognize that the floating frame was the essential feature that converted failure—or at best, mediocrity—into success.

The Melville and Macalpine design is illustrated diagrammatically in Fig. 3, where *AA* is the double helical pinion and *BB* is the large gear. The pinion shaft is supported in three bearings in the frame *C*. This frame is supported at its center by a section of I-beam *D*, which is fixed to the floor of the gear casing.

It will be seen that if the pinion shaft is flexibly connected to the shaft of the driving turbine, the elasticity of the supporting member *D* will allow the frame *C* to tilt in a clock-wise, or counter clock-wise direction to whatever extent is necessary to secure a proper alignment of the bearings of the pinion with respect to the bearings of the main gear.

While the Melville-Macalpine design fully demonstrated the correctness of the theory of the floating frame, it was soon seen that the essential principle might be more advantageously applied by supporting the pinion frame hydraulically. The advantages of the hydraulic support are three-fold. First, the removal of all direct metallic connection between the floating frame and the gear casing, eliminates in a large measure the noise of operation. Second, the hydraulic medium, being constantly circulated, contains a small amount of air entrained with it, which has a valuable cushioning effect that is not only further conducive to quiet running but which also gives a degree of elasticity to the system that will prevent the rapid contacting of the teeth from producing a hammer blow effect that might eventually result in pitting or crystallization. Third, the hydraulic pressure automatically adjusts itself in direct proportion to the torque, so that by the addition of suitable indicating instruments, the gear becomes the most accurate dynamometer yet devised for the measurement of large powers.

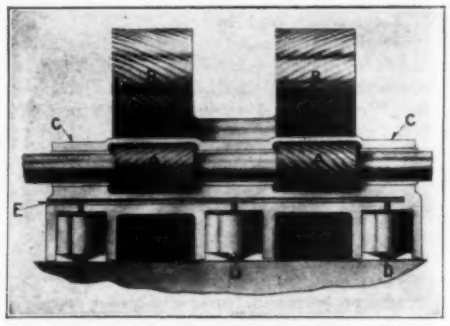


Fig. 4.—Single acting hydraulic floating frame.

The Westinghouse design is illustrated diagrammatically in Fig. 4. As in Fig. 3, *AA* is the double helical pinion, *BB* the driven gear, and *CC* the frame carrying the pinion shaft bearings. In the lower side of the pinion frame are three cylinders with pistons *DDD* which rest on a suitable beam or ledge in the gear casing. *E* is a passage communicating with all of the cylinders. It is evident that if fluid under sufficient pressure be introduced at *E*, the pinion frame *C* will rise and will literally float on the fluid contained in the cylinders. It is also evident that the lift of the pinion frame may operate a relief valve on the fluid pressure system in such a way as to maintain the pressure in direct ratio to the load on the floating frame.

If in the arrangement shown in Fig. 4, the direction of rotation is such that the upper teeth in the pinion are moving toward the observer, the resistance offered by the gear *BB*, will cause a downward thrust on the floating frame *C*, and the relief valve in the fluid pressure system will maintain the pressure in the hydraulic cylinders at the exact point required to balance the weight of the floating frame, plus the downward thrust due to the tooth pressure between the gear and the pinion. If the load is increased, the downward thrust on the pinion frame is increased and the pinion frame is depressed slightly, closing the relief valve in the fluid pressure system sufficiently to restore equilibrium. Conversely, if the load decreases, the pinion frame rises slightly, opening the relief valve, and relieving the excess pressure in the hydraulic cylinders,

thus automatically bringing the system into balance again. From the foregoing, it will easily be seen that the pressure in the hydraulic supporting cylinders is at all times an accurate index of the intensity with which the gear is working. The relief valve on the fluid pressure system is opened by a device that multiplies the movement of the floating frame so that the total travel of the latter over a range of load between full capacity and zero is only a few thousandths of an inch.

Inasmuch as the three supporting cylinders are in free communication with each other, the pinion frame is free to align itself in such a way as to bring about an even distribution of tooth pressure across the entire working face of the gear. The central cylinder is somewhat larger than the two others, and its piston acts as a pivot, on which the floating frame is balanced. The tilting of the frame required to bring about proper alignment does not therefore alter the height of the central part of the frame, from which point the relief valve regulating the fluid pressure in the cylinders is controlled.

The arrangement of supporting cylinders illustrated in Fig. 4, is single acting only, and consequently would not be sufficient for a gear that must operate in either direction, as is required in marine service.

When the direction of rotation is reversed, the direction of the thrust on the pinion frame is reversed, and consequently there must be another set of supporting cylinders on the opposite side of the floating frame. The sketch Fig. 5, illustrates the arrangement with two sets of hydraulic cylinders with their pistons *DDD* and *D'D'D'* bearing against suitable abutments in the gear case.

If the direction of rotation is such that the top of the pinion is moving toward the observer, there will be a downward thrust on the frame *C* which will be supported by the pressure of the fluid above the pistons *DDD*. If the direction of rotation is reversed, there will be an upward thrust on the frame *C*, which will be resisted by the pressure of the fluid beneath the pistons *D'D'D'*.

It is evident that the fluid pressure behind the supporting pistons could be maintained by means of a pressure pump discharging into the passage *E* and *E'* through a flexible connection. Fortunately, however, there is a

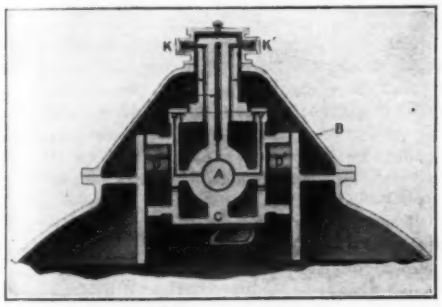


Fig. 7.—Section of double floating frame.

much simpler means which obviates the necessity for the added complication of auxiliary pumping apparatus.

For a long time it has been known that if oil is introduced into a rotating journal at the point of least pressure, and a means of egress is provided at the point of maximum pressure, the journal will have a decided pumping action, and will build up an oil pressure substantially equal to the maximum bearing pressure. For example, let Fig. 6 represent a rotating journal in which the pressure is downward, and the direction of rotation is indicated by the arrow. The maximum bearing pressure will be at the bottom of the journal, and the minimum pressure will be at the sides, especially if the bearing is cut back a trifle on the sides, as is common practice. If a hole be drilled through the bottom of the bearing, and piped to a pressure gage *B*, then when oil is introduced at *A* it will be found that the gage *B* will register a pressure practically equal to the pressure at the bottom of the bearing.

While, as stated above, this fact has been known in a general way for many years, no one appears to have endeavored to make any practical use of it, or to determine the quantity of oil that might be pumped in this manner. In connection with the development of the hydraulically supported pinion bearing frame this pumping action was exhaustively investigated, and it was found that, by suitably proportioning the bearings and supporting pistons, the former could deliver an ample supply of oil at a pressure sufficient to support the floating pinion frame when the gear is transmitting its maximum power.

Fig. 7 is a cross section through the floating pinion frame at the middle bearing. *A* is the pinion shaft, which in this instance is located directly above the main gear shaft. *B* denotes the upper part of the gear case. *C* is the floating frame and *D* and *D'* are two of the opposite supporting pistons. *E* is an upwardly projecting arm with oil passages *F*, *F'* and *G*. *HH* and *H'H'* are oil chambers extending throughout the length of the floating frame, and communicating with all three of the hydraulic cylinders on either side. The sections indicated by the letters *H* and *H* are not two separate chambers; what looks like a dividing wall is only a boss or post through which the oil passage leading the high pressure oil from the bearing is drilled. Similarly *H'* and *H'* constitute a single chamber. *K* and *K'* are the valves which automatically regulate the oil pressure, the details of which are shown to a larger scale later on. *L* is a pivoted link connecting the floating frame to the side of the gear casing, so that when the floating frame moves sidewise slightly in accommodating itself to the load, the upper end of the arm *E* will have a positive and considerably magnified corresponding movement.

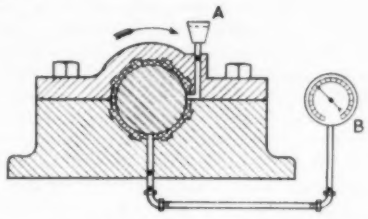


Fig. 6.—Pumping action of journal illustrated.

The operation is as follows: Low pressure oil is introduced into the upper end of the passage *G* in the upwardly projecting arm *E* through a connection that will be described in detail later. The oil passes down through *G* into the passage *J* which communicates with the top of all three pinion shaft bearings.

If we assume that the pinion is rotating in a clock-wise direction, the reaction between the teeth of the pinion and the gear will move the floating frame slightly to the right, and the upper end of the oil passage *F'* will be sealed by the valve *K'*. Each bearing will draw in low pressure oil at the top from the passage *J* and discharge it through the opening on the right, past a ball check valve into the chamber *H'H'* and into the hydraulic cylinders in which the supporting pistons *D'* are located. Since the exit of the passage *F'* is sealed by the valve *K'*, the oil pressure will build up behind the pistons *D'* until it just balances the side thrust of the floating frame corresponding to the load carried at the moment. The instant this pressure is exceeded, the pinion frame is forced slightly to the left. This movement causes the upper end of the passage *F'* to become unsealed by the valve *K'*, and allows the surplus oil to escape into the gear case from whence it is returned through the lubricating system to the passage *G*. The valve *K'* throttles the discharge from *F'* sufficiently to maintain the pressure behind the pistons *D'* constant at the degree required to balance the thrust of the pinion frame. If the load on the gear increases, the arm *E* moves slightly to the right, throttling the discharge from *F'* sufficiently to raise the oil pressure behind the pistons *D'* to the point where the system will be in balance again. Conversely if the load on the gear is decreased, the arm *E* moves slightly to the left, reducing the throttling of the discharge through *F'* so that the pressure behind the pistons *D'* is lowered until it just balances the decreased thrust of the floating frame.

When the direction of rotation is reversed, the action is just the same, except that the valve *K* and the oil passages and supporting pistons at the left, come into play.

Fig 8 is an enlarged section through the pressure regulating valve box, showing the details of the valves *K* and *K'*. The valve chambers contain simple sliding sleeves *M* and *M'*. These sleeves have shoulders and are held against corresponding shoulders in the valve boxes by springs bearing against the valve chamber covers. When the reaction of the pinion teeth causes the arm *E* to move to the right, the flat machined surface surrounding the outlet of the passage *F'* comes up against the end of the sleeve *M'* and prevents the oil from escaping from *F'*

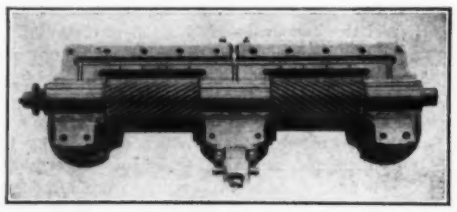


Fig. 9.—Showing lubricating channel in floating frame.

into the gear case. The sleeve being supported elastically by the spring, can yield slightly so that there will be no hammering action between the arm and the sleeve, as might be the case under rapid increase of load if the contact were rigid. As the oil pressure builds up beyond the point required to balance the thrust on the floating frame, the arm *E* moves to the left. The contact between the arm *E* and the sleeve *M'* is soon broken by reason of the latter coming up against the shoulder in the valve chamber, leaving an annular opening through which the surplus oil escapes into the gear case. The width of the opening thus formed adjusts itself automatically so as to maintain the oil pressure at exactly the pressure required to balance the thrust on the floating frame. If the pressure in *F'* tends to rise too high, the arm *E* recedes farther from the sleeve *M'* and makes the discharge opening larger. If the pressure tends to drop, the arm *E* approaches the sleeve *M'*, reducing the area of the opening and throttling the discharge sufficiently to maintain the required pressure.

The sleeves *M* and *M'* could, of course, be replaced by solid plugs, but they would be subjected to a considerable unbalanced oil pressure which would necessitate the use of inconveniently stiff springs to support them. By making these members hollow, they are practically balanced as regards oil pressure and the springs need only be stiff enough to insure that the sleeves are held positively in contact against their corresponding shoulders.

The principal advantage of the hollow sleeves is that the valve chambers are always full of oil at the same pressure as obtains in the system, and these valve chambers are consequently most convenient stationary points for attaching pressure gages *O* and *O'* for indicating the oil pressure in the hydraulic supporting cylinders. *N* is a pointer, the position of which indicates whether or not the pinion frame is floating properly. The position of this pointer may be observed by removing a small cap from the top of the valve box.

From what has been explained regarding the automatic regulation of the pressure of the oil which sustains the thrust of the floating frame, due to the reaction of the tooth pressure between the pinion and the gear, it will readily be perceived that the pressure of the oil is an exact measure of the force that is at the moment being exerted at the pitchline of the gears. This force multiplied by the pitchline speed in feet per minute and divided by 33,000 gives the horse-power that is being transmitted. Hence, by noting the pressure registered by the pressure gage *O* and *O'*, shown in Fig. 8 only a very simple calculation is required for calculating the power that is being developed. By connecting to the gear a continuous speed

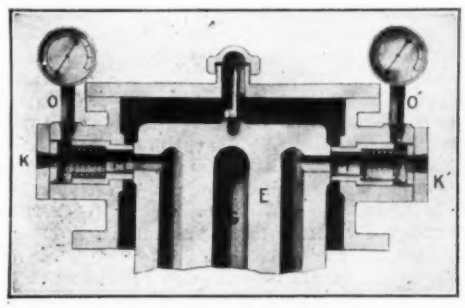


Fig. 8.—Section through pressure regulating valve box.

recorder, and a recording pressure gage, we may obtain charts from these instruments which will constitute a continuous log of the power developed over any extended period of time.

The gages *O* and *O'*, Fig. 8, may be located at any distance from the gear itself. When the gear is running, only one of the two gages indicates pressure. A reversal of the direction of rotation of the gear shifts the pressure reading to the other gage. If these gages were located on the bridge, the officer on duty could determine at a glance the direction of rotation of the turbine and the intensity with which it was working. These gages would also indicate unerringly the degree of promptness with which the engine room force carried out the instructions telegraphed from the bridge.

With a ready and accurate means of determining the power exerted, experience would doubtless indicate many ways in which this information could be utilized in detecting wastes and effecting important economies. For example, increased coal consumption without increased power would call for prompt investigation of the condition of the boilers, engines and auxiliaries. On the other hand, a comparison of the power developed and the speed of the vessel would avoid the necessity for any conjecture as to when it might pay to dock the ship for a general cleaning of the hull, and an examination of the propellers.

To avoid the necessity for absolutely rigid alignment between the turbine and gear, they should be coupled together by a reasonably long flexible shaft. In order to obtain this desirable connection, without sacrificing any space, the pinion shaft is made hollow, and the flexible driving shaft extends into the bore of the pinion shaft and is fixed to the latter at the end farthest away from the turbine. By this simple expedient the gear may be set close to the turbine, and still have the advantage of a connecting shaft of considerable length.

The coupling between the turbine shaft and the flexible driving shaft is so constructed as to allow the pinion to have a self-adjusting endwise motion without affecting the longitudinal position of the turbine shaft.

Lightning and Its Dangers*

Precautions To Be Taken and Means of Protection During Thunderstorms

By Sir Ray Lankester, K.C.B., F.R.S.

THE killing by lightning stroke on Sunday, June 14th, of seven people, including some little children who were taking shelter on Wandsworth Common against the drenching rain of a thunderstorm, shows that it is necessary to warn the public again and again of the danger which they thoughtlessly incur in thunderstorms —danger which they might to a large extent avoid, if not absolutely escape, by behaving, when caught in a thunderstorm, in accordance with the dictates of knowledge and experience.

These seven victims of the lightning were taking shelter from the heavy rain under the projecting boughs of two fairly large trees. Almost exactly three years ago several people who were taking shelter in an open shed at Epsom under similar circumstances were struck by lightning. All children in schools ought to be warned against seeking shelter in a thunderstorm under any solitary upstanding shed, tree, or group of trees. The danger arises from the fact that the shed or the tree stands out high above the general surface, and its top is the nearest point, for some distance round, to the thunder-cloud, and is likely to "attract" the electric discharge, or to serve as the passage of the electricity from the cloud to the earth. If the tree or the shed or such building were a good "conductor" of electricity, and were fixed deeply in wet earth or water (which is also "a good conductor" of electricity), no harm would be done; the electricity of the earth and of the cloud would quietly adjust themselves by aid of the projecting conductor. That is the service which "lightning conductors" perform. They are metal rods placed in high, prominent positions where they come into relation with the electrically disturbed thunder clouds, and as there is free passage through them to the vast area of deep-lying wet earth and subterranean water, the adjustment between the cloud and the earth is easily and quietly effected. As we say, the electric current "flows" through the conductor to—or it may be away from—the earth. But nothing is more fatal than a lightning conductor which is not properly "earthed." The upstanding metal rod must end below in a great plate of metal sunk in permanently moist earth, or, better, in flowing water. When there is not this regular and sufficient outlet for the electric current, as when a lightning conductor is broken from its "earth" or unprovided with such a base, the current behaves like a pent-up stream let loose, and dashes (so to speak) at and through anything leading ultimately to the soil. It is on this account that trees and wooden sheds are dangerous. They attract the electric current, but are not "good" conductors, and so do not provide a passage to the deep wet earth. The pent-up obstructed electricity takes the form of the "spark," or "lightning flash," instead of flowing quietly away. It is terribly destructive and erratic in its course, bursting and burning living as well as inert things on its way.

It is obvious that since it is dangerous to seek shelter in a thunderstorm under or at the side of a prominent tree, or a solitary shed, on account of their "upstanding" character, so it is dangerous to be yourself the most prominent object on a plain or a hill side during a thunderstorm. More persons are struck and killed in this way than when sheltering under trees. Sheep are often struck and killed when lying open on a hill side in a thunderstorm. What then is man, woman, or child to do when caught in the open in a thunderstorm? They may take shelter in a wood though not under an isolated tree, nor under a long high hedgerow. They should ask for shelter in any available house or cottage which is built for human habitation, and has weathered former storms. Failing these they may (as goats and sheep and cattle do) get under a low-lying rock-face, or into a ditch, or dry hole; or even (if the storm is close round them) lie flat on the ground. It is less dangerous to be wet through than to be dry, since wet clothes may and have before now saved a man's life owing to the fact that they are good conductors, and allow the electric current to pass away without obstruction. It is a very dangerous thing to be out in a thunderstorm, which is close to you, on a golf links, in a boat on a lake or wide river, or on the sea. The larger animals always seek shelter from a thunderstorm.

There are some people in this country who take the attitude of regarding the avoidance of unnecessary exposure in a thunderstorm as unmanly timidity. I have heard of such a one, who maintained that, according to the statistical records, only one person in a million, that is to say, forty persons in a population of 40,000,000, each year is struck by lightning in this country. Therefore, he remarked to his partner, when he was caught in a bad storm on a golf links, that the chance against his being there and then struck by lightning was more than a million to one, for there are 365 days in a year. His partner nevertheless crept under the lip of a shallow bunker and awaited events. The statistician walked half a mile across the deserted links toward the club house, and, when in mid-plain, was struck by a flash of lightning and severely injured, happily not killed. Later he admitted that his statistics had misled him. Very nearly everyone (he now recognized) is in the inside of a well-protected house during a violent thunderstorm. Not 40,000,000 of people are so foolish as to walk about on wide, flat plains over which an electric storm is raging. He admitted that probably not 400 in a year, either by compulsion or foolhardiness, thus expose themselves continuously during the full violence of a near thunderstorm. He now declared that one's chance of escape from being struck by lightning if one were fool enough to face a storm and take no precaution, was accordingly only 400 to 40, or 10 to 1—not nearly so good as the chance of a soldier in the front line of battle escaping death or a disabling wound, nor as the chance of recovery from a "major" surgical operation such as an amputation. A curious confirmation of the fact that ordinary human beings do as a rule seek protection from lightning stroke is seen in the fact that from time to time soldiers marching—in the same way as herds of animals when driven—have been destroyed in large numbers by lightning. Had they not been under military discipline they would have sought shelter.

When you are in a house during a close and immediate thunderstorm you should keep the windows shut and avoid placing yourself between two large and prominent conductors of electricity such as the water pipe or gas main (if your plumber has permitted you to know where they are) and the fire-place. If the house is a detached one or a corner house, and the storm is close, you will be acting reasonably if you retire into the basement until the storm is over. But you must be prepared to put up with criticism from the foolhardy. On the whole, the long rows of houses of fairly equal height in the streets of a great town are about as safe as any place during an electric storm. A railway carriage on the rails is theoretically very unlikely to be "struck by lightning," since the rails are a first-rate conductor. The Eiffel Tower, in Paris, being entirely built of iron, is a huge lightning conductor, and has been photographed in storms with forked lightning playing harmlessly about its head.

The inhabitants of towns are much more frequently struck by lightning than country folk, because living as a rule in the protection of the streets, they have no traditions and habits to guide them when they are out for a holiday and are overtaken by a thunderstorm on commons or in open country. They are both indifferent to the danger and ignorant as to the conditions under which that danger is greatest, and those under which it is reduced to a minimum. When they go into the country they do not know how to behave in a thunderstorm.

Learned writers on atmospheric electricity and thunderstorms do not trouble themselves to give information as to the precautions which a man should take to avoid being "struck," and what positions are the safest and what the most perilous. On the other hand, they have carried the knowledge of how to protect buildings by aid of lightning conductors to such a point that it is now possible to build a powder magazine which is practically safe from danger in any thunderstorm. This is effected by applying a network of conducting wire over its surface connected to upstanding metal rods, the bases of which are sunk in permanent subterranean water. The protection of property is more remunerative than the protection of human life.

It is important that everyone should be able to judge of the nearness or distance of a thunderstorm. The sound of thunder caused by the heating and sudden expansion of the air by the great electric spark which we call "a flash of lightning" travels a mile in 5 seconds. When there is an interval between the flash and the sound of the thunder of 2 seconds or more, the storm is for the time being at a safe distance, but when the interval is only a second or less the storm is close, and any prominent object near, or you yourself may be "struck."

The sparks an inch or two long which may be drawn from the brass collector of an "electric machine" are similar to the great electric sparks which pass as "forked lightning" from cloud to cloud or from a cloud to the earth. The little sparks of the electric machine make a sharp crackling noise, and may be made to perforate and traverse thin glass, leaving a hole to mark their passage. They are but 2 inches long. The spark which we know as "forked lightning" varies from 100 yards to a mile in length, and in some cases has been estimated to have been 10 miles in length. Its destructive power and the noise which it makes are in proportion to this difference of size. The ground is often "struck" by the lightning spark, and in sandy soils curious tubes of fused sand of some feet in length are sometimes found, which have been caused by the penetration of the lightning into the ground. They are called "fulgurites." The destruction caused by lightning is due more to the conflagrations which it starts than to the disruptive and bursting action of the current, serious as that is. Until the use of lightning conductors was introduced little more than 150 years ago, church towers and steeples, and, in fact, every large and prominent building, was destined to be struck by lightning and more or less completely destroyed in the course of a few centuries. The cathedrals and churches of this and other countries have been, in the course of history, repeatedly struck by lightning and often burnt to the ground. Though the lightning flash is a very difficult thing to deal with and takes the strangest and most unexpected paths when it strikes a house or other building, yet it is the fact that the danger of destruction of buildings by lightning has been greatly reduced. Competent electricians all over Europe are occupied in the endeavor to improve our present methods of protection by "lightning conductors."

There are several varieties of "lightning," or visible electrical discharges in our atmosphere. They are: (1) The line-like, wavy, often branching "forked lightning"; (2) sheet lightning; (3) St. Elmo's fire and the "brush" discharge; (4) ball lightning (also called "fireballs" and "thunderbolts"—a name applied also to meteoric stones); (5) the Aurora Borealis (or "Polaris," since it occurs at both poles of the earth). The "zodiacal light" is not, as has been supposed, an electric discharge. Forked lightning is the familiar, dangerous spark-like form of discharge, and "sheet lightning" is merely the reflection on clouds of forked lightning, too distant to be itself visible. St. Elmo's fire is a continuous brush-like silent discharge given off sometimes at the masthead of ships. A similar discharge is seen on mountain tops, and is described by Alpine climbers. It was seen and studied at the observatory on Ben Nevis a few years ago. The points of the roof, the poles, and even the hats on the heads of the observers (as sometimes the ice-axes of Alpine climbers) gave off this alarming, but harmless, luminous electric glow. Ball electricity is a very terrible and uncommon thing. It has, however, been often witnessed and described. During a thunderstorm a luminous ball from a few inches to a yard in diameter is seen moving near the surface of the ground. It may rise and fall and even enter an open door. Usually when it touches any obstacle it detonates, and causes enormous destruction, like a dynamite bomb. The Aurora Borealis, or "Northern Lights," better called Aurora Polaris, is a form of electric discharge in our atmosphere which occurs only near the Arctic and Antarctic regions. Its occurrence is not accounted for. It consists of curtain-like scintillations of colored light, and is accompanied by a hissing or rustling sound, and may be related in nature to the brush-like discharge of St. Elmo's fire. The spectrum of the aurora has been examined, and shows that it contains the gases of our atmosphere (including the rare new gas krypton) in an incandescent condition.

There are fewer thunderstorms and also fewer people killed by lightning annually in northern countries than in southern. This statement must, however, be qualified by the observation that thunderstorms are almost unknown in two widely separate southern lands, namely, Egypt and Peru. In the United Kingdom a much smaller number of persons (in proportion to population) is annually killed by lightning than in the United States of America or in France. The number of deaths from lightning stroke which occur in rural districts is ten times more numerous in proportion to population than those which occur in towns. This seems to be due to the protection afforded by the streets. Whether the smaller death rate from lightning in the United Kingdom as compared with the United States of America and with France is due to the less violence

* From the London *Daily Graphic*.

and frequency of thunderstorms in our islands, or to greater carelessness, and also to greater exposure in outdoor work in wild regions in the two latter countries, does not appear.

Two erroneous notions are generally heard of when a disaster such as that which occurred on Wandsworth Common is recorded. One is, that certain species of trees are more dangerous as shelter in a thunderstorm than others. It is said that more people are killed by lightning under oak trees and elm trees than under beech trees, and that no one has ever been killed under a birch tree! An attempt is made to connect this with the nature of the wood of these trees. But the facts are not established, and it is probable that the frequency, height, and usual position occupied by each of these trees are the causes of their apparently favoring or not favoring the deadly activity of a flash of lightning. The second erroneous notion is, that the lightning often prints off onto the body of a person struck by it, a picture, a sort of photograph, of the tree under which he or she was standing. Such tree-like pictures are often found on the skin of persons struck by lightning, and are caused by the dissolving of the colored corpuscles of the blood in the branching tree-like blood vessels of the skin, where the lightning has reached it. Sometimes an old tattoo mark (in the case of a soldier or sailor) gets mixed up with such "extravasations" of blood from the tree-like branching blood vessels, and so gives rise to marvelous stories as to the pictures wrought on the victim's skin by the lightning.

The Law of Distances of the Planets and Satellites

Some astronomers still adhere to Newcomb's opinion, that the distances of planets and satellites from their centers of attraction are not connected by any law. It is true that valid objection can be made to Bode's empirical law, according to which the approximate distances of the planets from the sun can be found by multiplying by 0.3 each term of the series: 0, 1, 2, 4, 8, 16, 32, etc., and adding 0.4 to the product. The fact that the law gives 38.8, instead of 30, for the distance of Neptune, is of small importance, for the law probably does not apply to the retrograde region of the system, in which Neptune is situated, as its retrograde rotation shows.

But Bode's law is contradicted by the "Mécanique Céleste" of Laplace, which constitutes a far more serious objection. In fact, Bode's law gives a very accurate value (5.2) for Jupiter and a very erroneous value (10 instead of 9.5) for Saturn. Any change in the distance of these two great planets that may have taken place in past ages must have been caused by their mutual attraction, but the maximum effect of this attraction, according to the "Mécanique Céleste," would be 14 times less than the departure of Saturn from Bode's law.

In presenting these facts during the course of an article in *La Nature*, Emile Belot points out that: "Slight discrepancies between an empirical law and observed facts do not afford a sufficient reason for rejecting the law. Kepler's three laws are only approximate. If Newton had taken, with regard to them, the skeptical attitude referred to above, he could not have proved the universality of gravitation.

"The only difference that exists between Kepler's laws and the law of planetary distances is that astronomers can easily explain the former, but have not been able to explain the latter, by Newton's law of universal gravitation. This failure, however, is not a sufficient reason for rejecting the law of distances *a priori*."

By adapting the ideas of Descartes to modern science, M. Belot assures his readers that he has succeeded in constructing a new vortex cosmogony, and in demonstrating a law of distances which is simpler and more accurate than that of Bode. This new law was submitted to the Académie des Sciences in 1905 by H. Poincaré.

The subjoined table of calculated and observed distances "leaves no room for doubt of the reality of this law," in M. Belot's opinion, and "it also shows an astonishing correspondence between the solar system and the system of Saturn."

M. Belot continues: "The *sudden* formation of all the planets at their present distances would be incomprehensible on Laplace's hypothesis of a single nebula, but it is entirely natural in my vortex cosmogony, which begins with the collision of two nebulæ, one vortical, the other amorphous, and endowed only with a movement of translation. In this collision, analogous to those which produce new stars, the vortical nebula is thrown into vibration and projects into the amorphous nebula as many concentric sheets as there are centers of vibration.

"In each of these planetary sheets, where the velocity of translation is diminished by the resistance of the medium, there is only one level, and in this level only one point, where the tangential velocity is opposable to the relative velocity of the vortical nebula. At these points only, in all of the sheets simultaneously, are formed vortices, the nuclei of future planets. This rapid and simultaneous expansion was observed in 1901, in the nebulous rings of Nova Persei.

"A century ago Lagrange and Laplace believed that they had proved, from the series given in the "Mécanique Céleste," the invariability of the mean distances of the planets and, consequently, the stability of the solar system. H. Poincaré, however, has shown that these series, instead of being convergent, are divergent, so that the stability of the solar system remains uncertain. But the law of distances removes this uncertainty. If, since the original formation of the universe, the distances of the planets had been changed by tidal action, mutual attraction, etc., and if these perturbations had accumulated, the results would differ for large and small planets, and for planets near and remote from the sun. In short, no law of planetary distances would now be recognizable.

"The fact that this law has existed unchanged from the beginning proves that the stability of the solar system has persisted during 100 or 200 million years, and is in no danger of being destroyed in the future, unless the system should come too near the nebula in Andromeda, which is approaching us with the menacing velocity of 200 miles per second.

"Thus the certain existence of the law of planetary distances proves at once the stability of the solar system and the cosmogonic insignificance of tidal action and the mutual attraction of planets or satellites."

EXPONENTIAL LAW OF PLANETARY DISTANCES.

$x_n - a = c^n$.

(x_n denotes distance of n the planet; a, radius of generating vortex; c, a constant.)

SOLAR SYSTEM.

$x_n - 0.28 = 1.883^{n\ \frac{1}{214.45}}$

No.		Distance Calculated	Distance Observed.	
1.	Zodiacal ring	0.2888	Observed	
2.	Zodiacal ring	0.2915	Observed	
3.	Zodiacal ring	0.3065	Observed	
4.	Zodiacal ring	0.3386	Observed	
5.	Mercury	0.3904	0.3870	
6.		0.4878	0.3870	
7.	Venus	0.6714	0.7233	
8.	Earth	1.017	1.0000	
9.	Mars	1.668	1.5236	
10.	Ceres, etc	2.893	2.75	
11.	Jupiter	5.201	5.2028	
12.	Saturn	9.546	9.5388	
13.	Uranus	17.728	(19.183)	(rétro)
14.	Neptune	33.183	(30.055)	(r tro)

SYSTEM OF JUPITER.

$x_n - 0.795 = 1.7175^n$.

1.	V	2.5125	2.55	
2.		3.7447	2.55	
3.	I	5.8713	5.933	
4.	II	9.4964	9.439	
5.	III	15.7396	15.057	
6.	IV	26.462	26.486	
7.		44.876	26.486	
8.		76.508	26.486	
9.	VI–VII	130.835	160–167	
10.		224.435	160–167	
11.	VIII	384.37	357	(rétro)

SYSTEM OF SATURN.

$x_n - 0.1 = 1.311^n$.

1.	Ring C	1.411	1.2 –1.5	
2.	Ring B	1.819	1.5 –1.96	
3.	Ring A	2.353	1.96–2.3	
4.	Mimas	3.054	3.07	
5.	Enceladus	3.974	3.94	
6.	Tethys	5.177	4.87	
7.	Dione	6.756	6.25	
8.	Rhea	8.826	8.73	
9.	Rhea	11.546	8.73	
10.	Rhea	15.098	8.73	
11.	Titan	19.762	20.22	
12.	Hyperion-X	25.877	24.5–24.2	
13.	Hyperion-X	33.89	24.5–24.2	
14.	Hyperion-X	44.40	24.5–24.2	
15.	Japetus	58.18	58.91	
15.	Japetus	58.18	58.91	
19.		171.67	58.91	
20.	Phebe	225.03	(214)	(rétro)

SYSTEM OF URANUS.

$x_n - 4.9 = 1.496^n$.

1.		6.396	(214)	(rétro)
2.	Ariel	7.138	7.04	
3.		8.245	7.04	
4.	Umbriel	9.908	9.91	
5.		12.390	9.91	
6.	Titania	16.105	16.11	
7.	Oberon	21.66	21.52	

Alcohol from Wood

The theorist's knowledge of the chemical structure of cellulose, grape sugar, and alcohol naturally leads him to desire to saccharize cellulose by treatment with acid, that is, to invert it into grape sugar, and then to convert the sugar obtained in this way into alcohol by fermentation. Since Braconnot demonstrated in 1819 that fermentable sugar is formed when substances containing cellulose are treated with acids many chemists have devoted themselves to experiments to find a good technical process for the obtaining of spirits from wood and other substances containing cellulose. Up to the end of the last century, however, no real technical success had been obtained in this field. There has been renewed activity in this branch of research for the last ten to fifteen years and great advances have been made, especially during the past five years, in our chemical knowledge of cellulose. A large number of cellulose factories produce alcohol by working over their waste liquors. Much larger quantities of alcohol can be obtained from the wood waste of sawmills in countries rich in timber. In discussing the extraction of alcohol from wood waste, Dr. R. Ditmar says in the *Umschau*:

"Both in the United States of America and in Canada there are sawmills which keep great fires going day and night to rid themselves of the wood waste. America seems to be the land in which the problem of extracting alcohol profitably from wood waste will first find a practical solution. The labors of European investigators form the basis of the experiments undertaken there. The process originally used was Classen's, described in the *Umschau* (1905, No. 26), in which the wood waste was treated with sulphurous acid. The details of the process were worked out in Herr Geheimrat Classen's laboratory at Aachen. American capitalists then built a laboratory at Highland Park near Chicago, and as good results were obtained here the Classen Lignum Company, which had acquired the Classen patents, built a factory for manufacturing wood alcohol on a large scale at Hattisburg, Mo. Wood shavings and sawdust were put into an iron digester lined with lead, the digester being a cylindrical vessel 10 meters long and 1 meter in diameter set in a horizontal position. The contents were moistened with a nearly saturated aqueous solution of sulphurous acid. The digester, which could hold about 1,800 kilos of wood waste, was then closed and set in rotation while the contents were heated to 150 deg. Cent., and the pressure inside rose to 7 atmospheres. After four to six hours the contents of the cylinder were taken out and washed with water. The sugary liquid thus acquired was fermented with yeast. About 8 litres of pure alcohol should be obtained from each 100 kilos of dry wood waste."

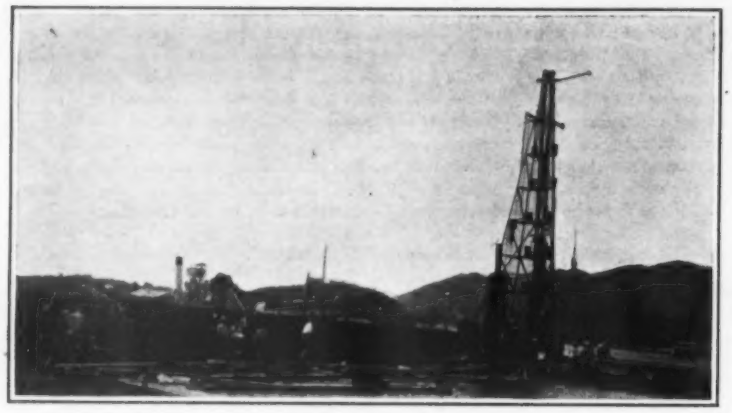
Various technical difficulties arose in the practical working of the process. Consequently, the Hattisburg factory was only run for a short time. After this the Classen process underwent two different forms of development in America. A branch of the Classen Lignum Company, called the Classen Chemical Company, built a new factory at Hadlock in the State of Washington which made use of a somewhat modified process.

Further experiments were also made, independently of the Classen Company, by two American engineers, Ewen and Tomlinson, who were acquainted with the Classen process at Aachen. Their process differed from Classen's in the construction of the digester. The good results obtained at a laboratory built near Chicago at the expense of the Wood Waste Products Company—where according to the investigations of Prof. Ruttan of Montreal 8.5 liters of alcohol have been obtained from 100 kilos of dry wood substance—led to the founding of a new company. This organization, the Standard Alcohol Company, after obtaining Ewen and Tomlinson's patents built a large factory for making wood alcohol at Georgetown, S. C. Dr. Ditmar says further in his summary:

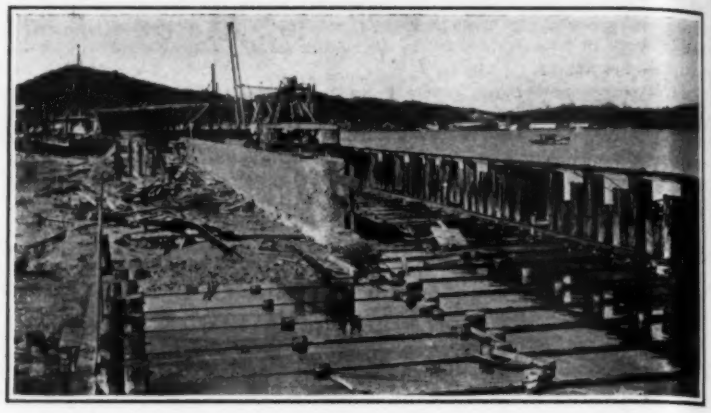
"The first mentioned factory at Georgetown came into the possession of the E. J. du Pont de Nemours Powder Company. This company controls almost the entire manufacture of powder and explosives in the United States and uses such enormous quantities of spirits in its numerous factories scattered over the entire country, that, although the factory at Georgetown produces more than 6,000 liters of spirits per day, it is regarded by the E. J. du Pont de Nemours Powder Company merely as an experiment station. It is, consequently, of the greatest importance to the company to produce the spirits it needs as cheaply as possible, and it is easy to understand that it is working with the greatest energy to perfect the manufacture of wood alcohol, and shrinks from no sacrifice in seeking the desired end. The factory at Georgetown, an old seaport of South Carolina, is in the immediate vicinity of three large saw mills belonging to the Atlantic Coast Lumber Company. Formerly these mills threw the wood waste that was not used in heating the boilers into the water or spread it on the surrounding fields; when this proved unsatisfactory the waste was burnt up in great furnaces. At the present time, 220,000 kilos of wood waste are worked over daily into alcohol."

The original Ewen and Tomlinson process used in the factory at Georgetown has been somewhat changed, so that sulphuric acid, not sulphurous acid, is now used in saccharizing the cellulose.

It would seem from these experiences in the United States that the manufacture of alcohol from wood waste may before long become a successful competitor of the ordinary distillation process.



Riveting the sheet piling of the new St. Thomas dock.



Piling of the new dock. At right-hand side is seen the iron pile facing.

The New Coaling Dock at St. Thomas

The First Unit of Extensive Harbor Improvements

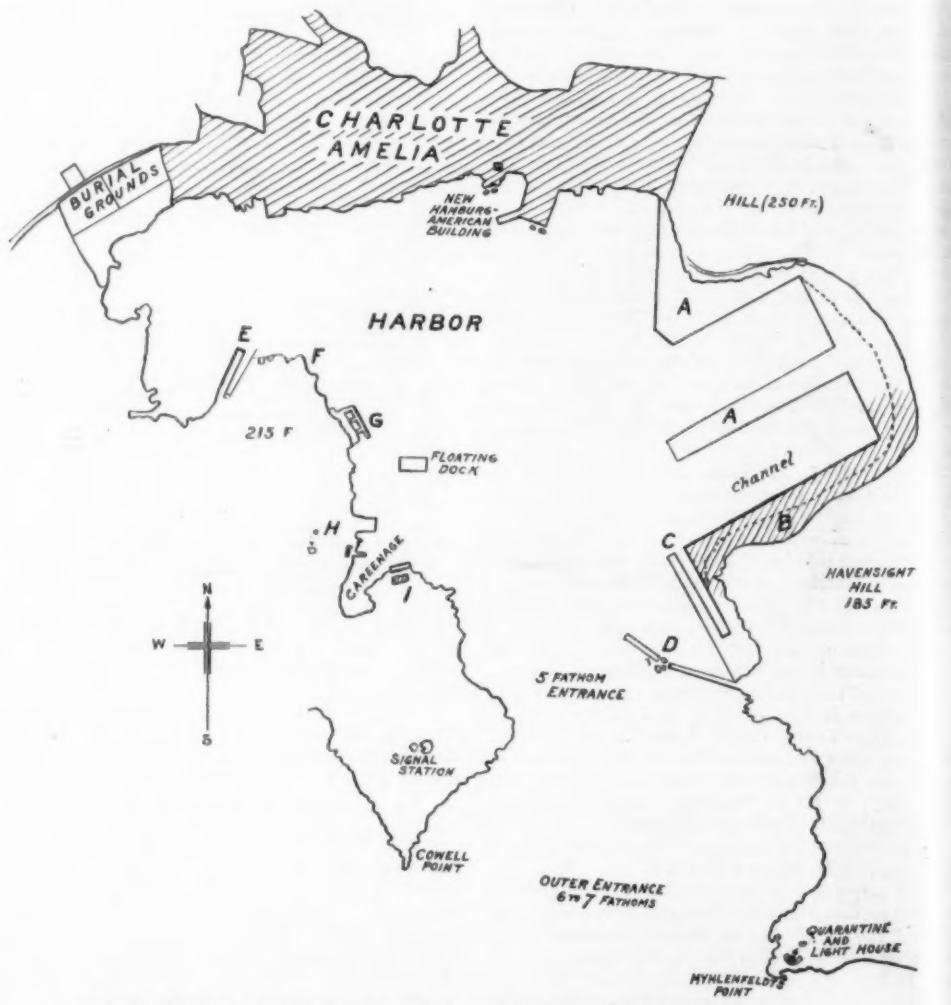
By C. T. Mason

BELIEVING that the island will benefit through the opening of the Panama Canal, the Danish people, as shareholders in a syndicate formed for the purpose, are building at St. Thomas what promises to be the finest coaling dock in the West Indies. It was at first proposed to carry out much more important improvements of the really splendid harbor, by reclaiming all the land at the eastern end and building a dock embankment along the entire shore, with a central pier 2,000 feet long, a drydock 800 feet in length, and a breakwater to further protect the shipping in case of heavy weather from the south. It was found impossible, however, to raise the required $7,000,000 in Denmark, and as only national capital was desired or advisable, the scheme had to be abandoned in favor of the present one. This consists in reclaiming about one third of the land and the erection of a large coaling dock capable of admitting vessels drawing thirty feet of water. The work was begun in April of last year and, at the rate it is being pushed, will be completed by October 31st.

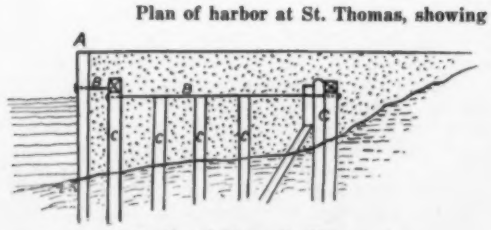
In order to make the approach practicable for vessels of the draft mentioned above, a channel varying from 500 to 400 feet wide is being dredged along the side of the dock. The excavated soil, consisting of sand, clay, and shells, has been used to build up the land required for the operation of the dock and also for filling in the spaces between the piling. This reclaimed land amounts to nearly one hundred acres and more than half a million cubic yards of soil have been employed in the construction.

Filling in with sand dredged from channel.

Casting supporting wall for back rail of coal crane.

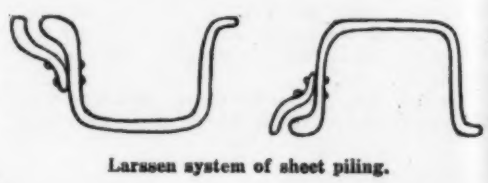


Plan of harbor at St. Thomas, showing location of new dock and improvements.



Sectional view of piling.

A, iron facing; *B*, iron bolts; *C*, *C*, wooden piles, the first and last with a square wooden runner on top.



Larssen system of sheet piling.

As to the dock itself, this has an iron facing of sheet-piling, known as the Larssen system, which consists of trough-like piles, seven eighths of an inch thick, that alternately turn the trough inward and outward, the piles being kept together by the edge of one sliding down in a ridge riveted on the edge of the other. They are kept in place partly by being driven into the solid ground and partly by being bolted to a system of wooden piles on the landward side. These wooden piles, of which over 5,000 were used, are of American yellow pine, averaging from 8 to 14 inches in diameter and from 16 to 50 feet long. The space between the piles will be filled in with soil dredged from the bottom of the channel. The system of iron facing employed has been used to great satisfaction in similar work, particularly at Kiel, but never on such an extensive scale.

When completed, the pier will measure 2,100 feet in length, with a depth along the side of 31 feet and a height above mean sea level of 8.25 feet. Two coal cranes (to begin with) will be installed, each having a capacity of 100 tons an hour. For the lighting and operation of the dock by electricity a power house (built on hardwood piles with a concrete foundation) has been erected, and here a Diesel motor of 300 horsepower has been installed, and another of similar capacity will shortly be added. The lighting will be provided by fifty metallic incandescent lamps of from 200 to 300 candle-power, placed in two rows. A pump house for supplying sea water for cooling the motors has also been put up and connected with the engine rooms. It is expected that the system, besides supplying all the needs of the dock, will also be called upon to furnish the lighting for the city, now illuminated by gas.

It is the intention of the syndicate to provide oil for vessels patronizing the port, and the necessary storage tanks will be erected as soon as the needs of the dock are properly ascertained. The work has been carried out entirely by Danish engineers and mechanics, of whom about fifty were brought out from Denmark; while native labor has found employment to the extent of about three hundred persons, the pay of these natives being 60 cents a day for unskilled hands and $1.25 for mechanics.

The photographs reproduced, and taken expressly for this article, are by Lieut. Olsen, one of the engineers of the syndicate, to whom the writer is indebted for the information given.

The Altitude Record Again Broken

AGAIN the altitude record has been broken, this time by the German aviator Oelrich, who has reached an altitude of 8,000 meters, or 26,250 feet. At 14,800 feet he found breathing difficult, and was obliged to make use of his oxygen apparatus. This, however, did not help him much toward the end of his ascent, and he suffered decided feelings of sickness and giddiness. If greater heights are to be attained, Oelrich asserts that special provision will have to be made for breathing, and also some kind of protection for the body against cold and reduced air pressure.

A Surge Tank for Hydraulic Power Plants

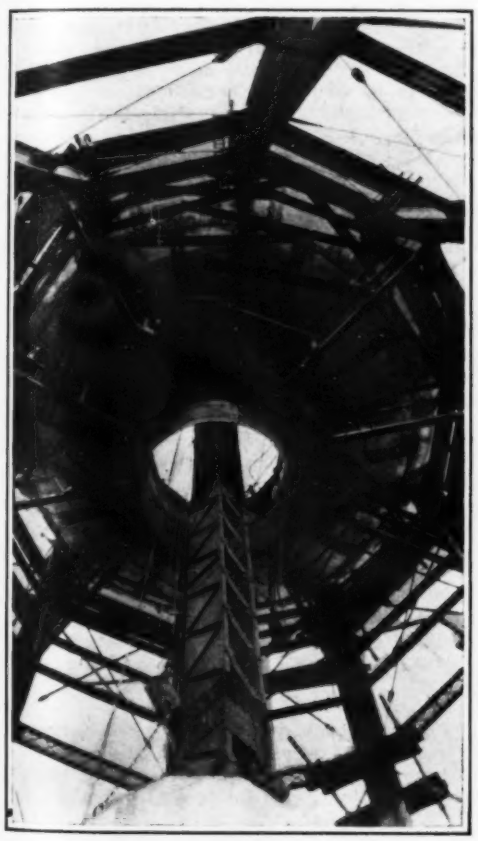
A Simple Method of Controlling the Flow of Water in Long Pipe Lines.

In hydraulic power plants which are served by long pipe lines between the reservoir and the water wheels, when there is a sudden demand for more power, necessitating an increased supply of water, there will ordinarily occur an interval of time after the valves are opened before the necessary increased flow is established in the pipe line. And on the other hand, when the valves at the turbine are suddenly closed, severe strain is thrown on the pipe line in checking the momentum of the long column of water. To remedy these conditions modern hydraulic engineers make use of a hydraulic regulating device known as a surge tank, which is permanently connected with the pipe line at a convenient point, usually as near the turbines as possible.

One of the largest surge tanks ever constructed has recently been erected at the plant of the Salmon River Power Company at Altmar, N. Y., to take care of the back pressure or surge loads on a very large pipe line supplying water for power purposes. This line is 9,500 feet long and ranges from eleven to twelve feet in diameter, and the volume of water and the variations in pressure to be handled are exceedingly large.

This great tank is a cylinder with a hemispherical bottom 105 feet in height and 50 feet in diameter, and the 12-foot riser that connects it with the pipe line is 100 feet high, bringing the top of the tank 205 feet above the ground. Close to the power plant there is a section of the pipe line, called the distributor, with which the pen stocks leading to the various turbines are connected, and in this distributor is placed a great cast steel tee, which forms the connection with the riser that leads to the surge tank proper. This riser is 12 feet in diameter, the same size as the distributor pipe, and connects the latter with the bottom of the tank. Within the tank this riser is continued about two thirds of the height of the tank by a section 10 feet in diameter, which in effect divides the contents of the tank into two distinct parts. At its lower end this interior riser is provided with openings, termed differential ports, that form a connection of the space within the riser with the main body of the tank, the function of the ports being to modify the flow of water to and from the tank, and divide the flow between the main body of water in the tank and that within the riser. When there is a demand for more power from the plant, and the valves at the turbine are suddenly opened, the differential ports, by retarding the flow of water from the tank, apply the full accelerating head to the pipe line, and at the same time the tank makes up any deficiency in the volume of water required at the turbines until the flow in the pipe line has accommodated itself to the new conditions. On the other hand, these so-called valves check the rise in pressure more gradually when the load is thrown off. In the wooden flooring at the top of the tank suitable traps are placed to permit of the passage of air during rapid changes of water levels in the tank, which changes are liable to be quite large and of frequent occurrence.

The tank and its fittings are substantially constructed of steel, and it is housed in to protect it from the weather, and provision is made against freezing.



Derrick used in erecting the tank.

Riser and tank as seen from below.

Surge tank and pen stocks.

Damascene Steel

ACCORDING to an article in the *Internationale Zeitschrift für Metallographic*, by W. Guertler, damascene steel contains 1.0 to 1.6 per cent carbon, and consists structurally of extremely small grains of cementite in a ground mass of ferrite. The characteristic appearance and properties of the steel are due to alternations of cementite-poor and cementite-rich zones. Prolonged heating at high temperatures, as recommended in the earlier literature, cannot possibly give the desired result. The most promising method seems to be to heat suitable steel, in which an extremely fine-grained structure has been induced, to a temperature below 700 deg. Cent. for a sufficiently long period. The necessary preliminary structure may be produced by very rapid cooling, or by severe working above the eutectoid temperature.—*Journal of Franklin Institute.*

A Novel Wax Bleaching Plant at Brentford (England) consists essentially of an electrically driven blower, an air cooler, a battery of five ozonizers, and the vessel in which the material is treated. The ozone produced is led to the bottom of the treating vessel, and passes up through the molten wax in fine jets, effecting the bleaching of the wax.

The Riddle of Mars

How the Planet May Be Saving Itself from Death by Irrigation

THE planet Mars has a special fascination for the layman as well as for the astronomer, inasmuch as it is probably the only member of the solar system, our own earth of course excluded, on which the existence of animal life is at all likely. What is the character of that life? For the solution of an astronomical problem, circumstantial evidence is all that is available, and certainties can never be available from such evidence alone. Prof. Percival Lowell's views with regard to the nature of Mars's canals and oases were reached mainly by direct observation. Their rhythmic waxing and waning is frequently emphasized, and in "Mars as the Abode of Life" he writes: "Confronting the observer are lines and spots that but impress him the more as the study goes on with their non-natural look. So uncommonly regular are they, and on such a scale, as to raise suspicion whether they can be by nature regularly produced."

The regularity, the character, and indeed the very existence of these minor markings are, however, questioned by some astronomers; an endeavor is therefore now made by Mr. C. E. Housden, a member of the British Astronomical Association, to solve the riddle of Mars from quite a new direction, to-wit: An analysis of and deductions based mainly on terrestrial irrigation experience from the extensive color changes which have from time to time been noticed even in small telescopes in the main features of the Martian disk, the existence of any minor markings being, to begin with, ignored as far as possible. Mr. Housden has set forth his views in a book entitled "The Riddle of Mars," published by Longmans, Green & Co., and from this book the following paragraphs are abstracted by permission.

COLOR CHANGES ON MARS.

When Mars is viewed even through a moderate-sized telescope, three distinct colors can be clearly made out on its disk. These are:

(*a*) Two comparatively small circular patches of white at its poles.

(*b*) A broad band of ocher occupying very nearly the entire center of the planet.

(*c*) Two more or less connected narrower bands of blue-green lying between the white polar caps and the central ocher band.

Examination of the circular patches, which are probably polar snows, has shown that, as they melt, the decreasing caps are bordered by a dark blue band which follows and narrows with the dwindling caps, and can thus be only water. That it is so is now generally granted. This band, however, rapidly disappears, the areas originally occupied by it showing first dark brown and then fading out to ocher, leaving ultimately a small kernel of white bordered by a very narrow blue band in the center of the vast ocher area thus exposed to view.

The snow thus collects for about seven and one half Martian months, is about three such months in nearly all melting off again, and does not either perceptibly increase or decrease during the remaining one and a half months.

The ocher-colored areas on Mars, which do not change to any marked extent, are now generally admitted to be deserts.

The extensive blue-green areas are, it is further now admitted, not "seas," as it was at one time supposed they were. Their coloring is accounted for by two rival theories: The one holds that they are what were once Mars's ocean basins, and that they are, in consequence, depressed areas now covered twice a year with vegetation; and the other, that they are what on earth would practically be permanently frozen swamps. The former view is the more acceptable.

The blue-green all over Mars is at a minimum about mid-January and mid-July of the Martian year, and at a maximum about mid-April and mid-September. If the color changes were due to the freezing and unfreezing of swamps, the changes noticeable in the northern and southern hemispheres should be radically different. The blue-green areas are therefore, without reasonable doubt, mainly depressed areas covered with vegetation which waxes and wanes, the time from minimum to minimum being somewhat shorter in the warmer polar hemisphere, in which the snow is at the time melting, than in the opposite and at the time cooler one.

For vegetation to wax and wane year in and year out, successive waterings, either natural or artificial, are needed. But the only water on the planet is at the poles. Hence, that water must be led to the spots where it is needed.

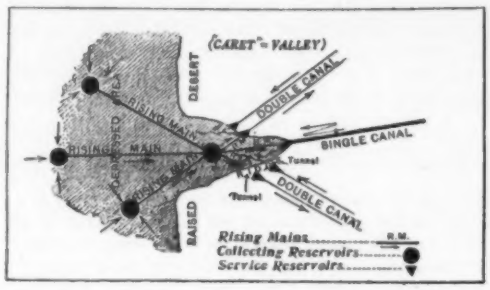


Fig. 1.—Details of flow through a "caret" on Mars.

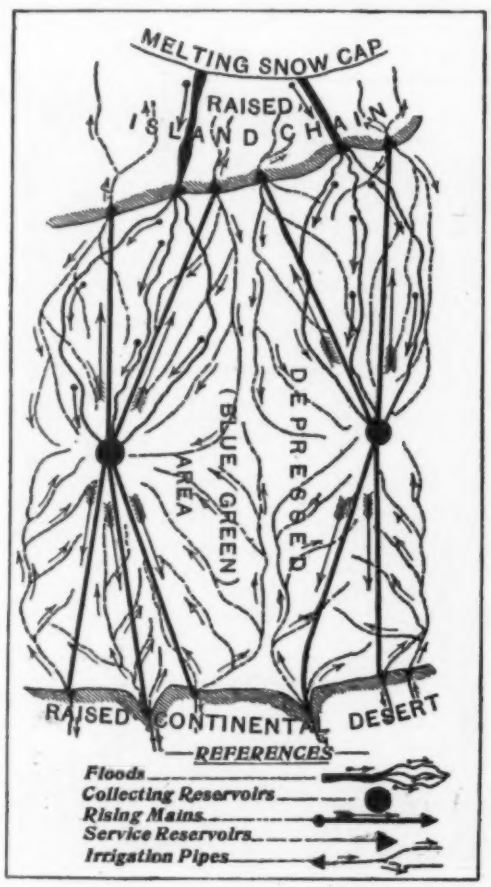


Fig. 2.—The irrigation of a depressed area in Mars's southern hemisphere.

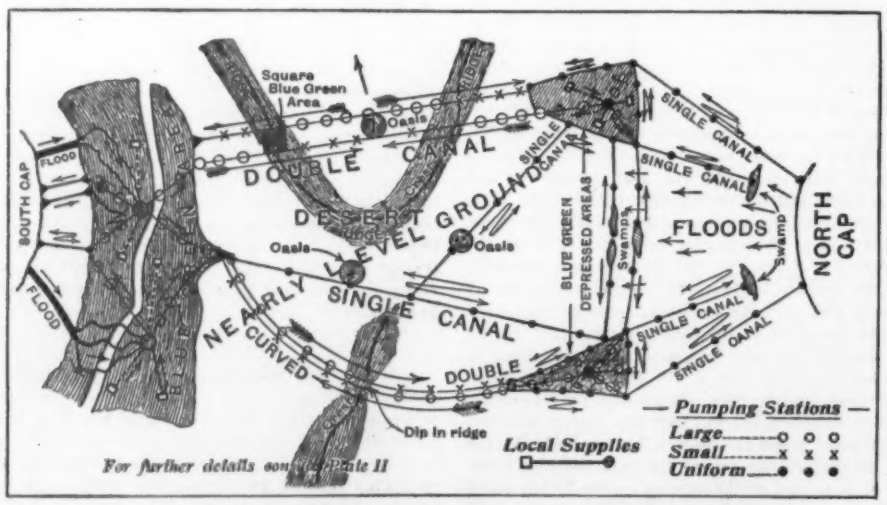


Fig. 3.—Plan illustrating the transport of water across Mars.

FLOW OF WATER ON MARS.

The polar cap in Mars's southern hemisphere must, at its maximum, be a vast snowfield, as its average diameter is then about 3,600 miles, and the maximum area covered by it about 10,500,000 square miles.

The whole cap (area 10,500,000 square miles), however, practically all melts off in about three Martian months, or say 15,000,000 seconds, or at an average rate of $\frac{105}{150} = 0.70$ square mile per second.

Taking the average depth of water available from the melting of the snow at half a foot over the cap's entire area, due to a 5-foot depth of snow (and a greater depth, owing to the rapidity with which it melts, could not well be calculated on), the rate of flow during the time the cap is melting would be a continuous one of $\frac{1}{2} \times 27{,}878{,}000 \times 0.70 =$ say, 10,000,000 cubic feet per second, or, in its usual abbreviation, 10,000,000 cusecs.

The water from the melting cap cannot drain into a neighboring sea as it does on earth, but must flow away overland to the so-called "seas" (depressed areas) of Mars's southern hemisphere.

With a depth of 2 feet and a water surface slope of 1 in 3,600, the velocity generated on Mars would be 0.84 feet per second, and we should need a series of channels having a combined width of $\frac{10{,}000{,}000}{2 \times 0.84} =$ say 6,000,000 feet, or about 1,200 miles.

To provide artificial carriage in open channels of low depth and low velocity for such a large discharge as 10,000,000 cusecs would be a matter of considerable difficulty; the water set free on the first melting of the southern polar cap must therefore mainly find a natural escape through very flat existing openings having a total combined width of either about 1,200 miles and a 2-foot depth through which the water flows with a velocity of 0.84 feet per second, or a combined width of about 350 miles with a depth of 4 feet and a rate of flow of 1½ feet per second, or something in the neighborhood of these limits.

To make use of the water so locally collected or collecting it would be necessary, as in the case of the southern hemisphere, to pump it from where it is collecting to where vegetation is at the time in full growth all over Mars.

HOW FLOWING WATER IS UTILIZED.

The simplest, and in the long run perhaps the most economical, way in which this could be effected under similar conditions on our own earth, would be to pump the water through water-tight pipes or conduits from the low points at which it is collecting up to service or distribution reservoirs situated on convenient high points within or, preferably, on the margins of the areas to be irrigated, whence it could be carried in the required directions through water-tight pipes under a static head, from which pipes and from smaller pipes branching therefrom, and from still smaller pipes branching from these branch-pipes, the water could be distributed all over the areas needing irrigation, in the form of "regulated artificial rain showers," through mechanical sprinklers worked under a pressure head.

The distribution of water to a depressed area of Mars's southern hemisphere might be somewhat as illustrated in Fig. 2.

The actual continuous flow from Mars's south polar cap is probably a large one—under the assumed conditions, 10,000,000 cusecs—and would need a large number of pipes, taking off, however, from a large number of distribution centers, to allow of the available supply being even only lifted from collecting to service (distribution) reservoirs.

The diameter of each pipe would further be limited by the horse-power which could be economically devel-

oped at each pumping station along it, and could not therefore be very great.

If the pipes are buried underground, the only evidence of the direction followed by the water-conveying pipes (rising mains) would be the pumping stations, many miles apart, on them.

The distribution pipes, under static pressure, leading from the service reservoirs would not show at all.

Assuming, so as to have something definite to work on, that each "rising main" has a diameter of 6 feet, and that the rate of flow through it is Mr. Lowell's ascertained rate of flow from north to south in the Martian canals, viz., 2.1 miles per hour or 3.1 feet per second, the discharging capacity of each pipe would, as the area of a 6-foot diameter circle is 29.6 square feet, be $29.6 \times 3.1 = 90$ cusecs. As the continuous flow to be arranged for is 10,000,000 cusecs, we should need $\frac{10{,}000{,}000}{90}$ = say, 120,000 such pipes for the purpose.

These pipes could be grouped together according to the quantity of water to be raised to each service (distribution) reservoir.

Twenty pipes placed parallel to one another and say 100 feet apart, so as to allow of room for the pumping stations needed on each one, would, if laid in turfed banks and cuttings (so as to allow of these large pipes being graded), or if from any other cause (such as the irrigation for local food supplies of the land lying immediately above them) the line of pipes was rendered visible, if viewed from afar, have very much the appearance of the streaks to be seen on Mars and designated its "canals," inasmuch as it would show a straight, very long, very narrow, and uniformly wide, continuous shading.

Through such a "canal" $100 \times 20 = 2{,}000$ feet wide, $90 \times 20 = 1{,}800$ cusecs would be continuously pumped.

With a thousand pipes so arranged, the flow could be increased to a continuous one of 90,000 cusecs, and the width of the "canal" would be 100,000 feet, or close on 20 miles.

Now, as such streaks, in some cases over 2,000 miles long and on the average about ten miles in width, have been mapped as traversing in straight lines, both the ocher and blue-green area of Mars in all directions, it is only a reasonable inference that they are due to a somewhat similar cause, and that they mark the directions in which water is being pumped through groups of parallel pipes from generally low-lying to higher points on the planet.

Such streaks do not show until some considerable time after the polar snows commence to melt, and are therefore other than the broad ill-defined ones, which indicate the directions followed by the floods from the south polar cap.

The water raised to convenient points on the northern margins of these southern seas would not only be needed for the irrigation of, say, half the area covered by them and the south island chain, but a fair portion of it, about one half, would have to be pumped right across the intervening desert tract for the irrigation of the blue-green areas of the northern hemisphere, whose total area is somewhat less than a moiety of those in the southern hemisphere. To allow of this being done, we should need a number of "canals" crossing the central Martian desert, and connecting the extensive blue-green areas of Mars's southern and northern hemispheres one with another. These "canals" would have an average length of about 2,000 miles each. On the other hand, the lengths of the "canals" crossing the northern blue-green areas may be put at about 1,200 miles.

The average length of each of the separate sections through which water would have to be pumped from collecting to service reservoirs would thus, at the most, be $\frac{1}{4}$ $(1{,}200 + 1{,}200 + 2{,}000 + 1{,}200) = 1{,}400$ miles.

Six months later, on the melting of the northern cap, water would have to be similarly conveyed across the central desert from north to south. The amount so available would perhaps, as the maximum area covered by the northern cap is 7,000,000 square miles, be a continuous flow of $\frac{7}{10} \times 10{,}000{,}000 = 7{,}000{,}000$ cusecs. This is on the supposition that the full amount available could be brought into use.

If out of the 10,000,000 cusecs available from the southern polar cap, we assume that 7,000,000 cusecs will suffice for the irrigation of the blue-green areas in the southern hemisphere and 3,000,000 cusecs for that of the northern blue-green areas, the amount available for transmisdon from north to south will be $7{,}000{,}000 - 3{,}000{,}000 = 4{,}000{,}000$ cusecs, or 1,000,000 cusecs more than from south to north; but another 3,000,000 cusecs would still be needed for the irrigation of the southern seas.

If the intervening desert was a level plain or only undulated slightly, the pumping stations needed along the "canals" would be much the same distance apart and of much the same power, and water could be pumped from south to north, or north to south, through a single "canal," by simply reversing the direction of flow; even if it was necessary to pick up *en route* a small, blue-green area (an "oasis") situated in the intervening desert tract. A single line of pipes ("canals") carried past or through the higher end of the "oasis," from which the water required for its irrigation could be distributed by gravitation, would suffice, and the flow would be somewhat as illustrated in Fig. 3, "single canals."

A double set of pipes would, however, be needed, if the ground over which water has to be pumped is far from level. Appreciable intervening heights would have to be surmounted, and a line of pipes with a different set of pumping stations—powerful ones on the up-grades and smaller ones on the down-grades—provided for the south to north flow and the north to south one, the directions of flow being somewhat as shown in the "double canals" illustrated in the above referred to Fig. 3, the "canal" carrying the north to south flow being probably the wider one of the "double."

In Mr. Lowell's and other maps of Mars are shown many "canals," both single and double, either directly connecting the extensive blue-green areas in the two polar hemispheres together, or more frequently picking up on the way a small blue-green area; and, strange to say, in many instances a "double canal," with one "canal" wider than the other, is used for the latter purpose with, in some cases, the small blue-green area situated exactly between the twin "canals." Two different kinds of blue-green areas are, according to Mr. Lowell's maps, so picked up—small dark, round spots (the "oases" of Mars) and large square areas of a lighter blue-green, as shown in Fig. 3.

From such an arrangement of pipes ("canals") it would appear that Mars's desert "oases" are situated in valleys, and probably mark the sites of desert water supplies, as well as the sites of present centers of population; in other words, cities and towns and their surroundings, to which the produce of the crops raised in the extensive blue-green areas of Mars is conveyed by some method of transport running along the "canals" which serve them, and that the square, lighter-colored areas mainly situated at "double canal" crossings are relatively small patches of cultivation situated on an intervening height.

The spots ("oases") in the extensive blue-green areas, on the other hand, probably mark points at which water is collected, and thus differ to some extent in character from the dark "oases."

The rise from the center of an extensive depressed blue-green area to the raised central desert is probably negotiated through a valley leading therefrom, as shown in the sketch above (Fig. 1). Such markings on Mars are designated by Mr. Lowell as its "carets."

A possible solution of the flow of water from Mars's polar caps is thus arrived at. In its first rush from the melting caps the water is carried forward by gravitation and comes to rest at low-lying points on the planet, to be then pumped up to high-level service reservoirs through the Martian "canals," which thus correspond to what on earth are known as "rising mains."

From these service reservoirs the water is mainly distributed to the lands to be irrigated by gravitation through pipes under static pressure, but may be also, in some cases, perhaps, distributed through open channels.

WATER FROM POLAR CAPS INSUFFICIENT.

The extensive blue-green areas of Mars cover about 21,000,000 square miles of its surface. The south polar cap when at its maximum covers about 10,500,000 square miles; therefore half a foot of water on the latter area would suffice to cover only the blue-green areas to a depth of 3 inches.

The north polar cap has a maximum area of 7,000,000 square miles, and the water available from it could only cover all Mars's blue-green areas to a depth of $\frac{7}{10} \times 3 = 2$ inches, supposing always that it can be fully utilized.

Such light coverings would be quite inadequate for the maintenance of vegetation, and a further supply for the half-yearly irrigation of Mars's blue-green areas is clearly needed. On the assumption that a 9-inch covering in six Martian months is the least which will, under the assumed conditions, suffice for the maintenance of vegetable life on Mars, the deficiencies to be made good would be thus 6 inches and 7 inches, respectively.

The assumed rate of flow from the south polar cap has been taken at 10,000,000 cusecs; this is sufficient to cover all Mars's blue-green areas to a depth of 3 inches in three Martian months, and would cover them to a depth of 6 inches in six Martian months. The quantity of water needed for a 9-inch covering in six months from Mars's assumed underground supplies would thus be a continuous flow of 15,000,000 cusecs when the south polar cap is not melting, and therefore 5,000,000 cusecs when it is melting.

Assuming then that a continuous flow of 15,000,000 cusecs will suffice for the full irrigation of all Mars's blue-green areas, we may proceed to try to ascertain the power which would be needed to effect this purpose when the water is pumped through pipes or conduits 6 feet in diameter at a rate of 90 cusecs per pipe or conduit.

POWER FOR PUMPS.

As we have seen, the average length of each "canal" from collecting reservoir to service reservoir would be probably, at most, about 1,400 miles, and we should therefore require ten pumping stations of 1,150 N.H.P. on each 6-foot diameter pipe. The power required for each pipe would be thus $1{,}150 \times 10 = 11{,}150$ N.H.P.; and as to deal with a continuous flow of 15,000,000 cusecs the total number of pipes needed would be 170,000, the total power required to work the entire system would be $170{,}000 \times 11{,}500 =$ say 2,000,000,000 N.H.P. Something would have to be added for the "canals" needed to help a portion of the water set free from both the melting polar caps from their vicinity, and we may therefore put the sum total of the power which would have to be developed at 2,500,000,000 N.H.P. This is only about four thousand times as much as that under development at the Niagara Falls alone, which is 650,000 horse-power, and much under that in daily use on our own earth, and therefore not beyond development.

In western Australia 5,600,000 gallons of water are daily pumped at a rate of 10 cusecs through a 30-inch steel pipe and over a rise of 1,290 feet from a reservoir at Perth to the mining center of Coolgardie, 351½ miles distant therefrom. Coolgardie is situated on a tableland which is one of the driest places on earth, the maximum temperatures recorded in its neighborhood being 132 deg. Fahr in the shade and 157 deg. Fahr. in the sun. The distance from the storage reservoir at Perth to the service reservoir at the top of the intervening rise of 1,290 feet, from where the water gravitates under static pressure 43½ miles to Coolgardie, is 308 miles, and there are eight pumping stations in this distance, their average distance apart being thus 38½ miles. The average horse-power likely to be needed at each pumping station works out to 330 N.H.P.

With eight pumping engines of this power, 5,600,000 gallons of water could on Mars be daily forced up a height of 1,290 feet through a similar 30-inch pipe line having a total length of about 680 miles, or more than twice the distance from Perth to the service reservoir.

Unless water is obtainable from the interior of Mars, its polar caps and shallow swamps (the latter are to be found there) would alike soon cease to exist, and the planet roll through space a dead and dried-up world, which at present is certainly not the case.

Evaporation from the water so obtained and used in the irrigation of all the blue-green areas would supply the water vapor known to be present in the Martian air, a portion of which vapor, when carried by the Martian winds to the planet's polar regions, is there deposited, owing to the intense cold there met with, mainly in the form of ice spicules, to later on melt and be again used for irrigation.

A considerable portion of the water used for the full irrigation of the blue-green areas would filter back to the underground supplies from where it was obtained and replenish them; there would thus be only a partial annual drain on these supplies.

For natural vegetable growth dependent on rainfall (assuming such a fall), a much larger supply of water than a 9-inch covering in six Martian months would not only be needed, but a large portion of the rain falling on the surface of Mars would be wasted by falling at the wrong time and also by falling on deserts where it would be of no use. The least amount which would probably suffice would be a 24-inch fall in six Martian months.

Melting Points of Refractory Oxides

THE melting points of some refractory oxides have been determined by the Bureau of Standards in a graphite resistance vacuum furnace. The temperatures were measured by an optical pyrometer and heating curves were plotted. The production of smoke from some oxides was found to be a source of error, as the smoke interferes with the use of the pyrometer. These valuable experiments are described by the investigator, Mr. C. W. Kanolt, in Vol. 10, No. 2 of the *Bulletin* of the Bureau.

The Building Fund of the Royal Geographical Society has received a contribution of $5,000 from the government of Australia.

Result of First Contest for Safety in Aeroplanes, in France

Remarkable Performance of the Sperry Gyroscopic Stabilizer

A YEAR ago we announced an international competition for the development of a safe aeroplane. Over $100,000 in prize money was to be awarded, there being a Grand Prix of $80,000 for the safest aeroplane or device applicable to an aeroplane to make it safe. Great latitude was given inventors and no strict rules regarding the judging of the machines and devices were drawn up. Consequently it was a very difficult matter for the judges to decide what constituted the greatest advance in the line of safety. They decided not to award the Grand Prix, but to hold it for a second competition. There were fifty-six entries accepted and twenty-one competitors appeared. But two prizes were awarded, although seven contestants were given sums ranging from $3,000 down to $200 to encourage them. The total sum distributed was $26,200, as follows:

$10,000 to the Sperry gyroscopic stabilizer.
6,000 to the Paul Schmitt biplane with variable incidence planes.
3,000 to the Candron biplane.
2,000 to the Doutre stabilizer, a pressure plate device.
2,000 to the Avisto carburetor.
1,600 to the Etevé stabilizer.
1,000 to the Moreau aeroplane (automatic stability by pendulum seat).
400 to the Robert safety parachute.
200 to the Philippe and Perron starter.

The Sperry stabilizer was fully described in the SCIENTIFIC AMERICAN of June 7th, 1913, and August 8th, 1914. The tests made before the judges on a Curtiss aeroplane by Lawrence Sperry and his mechanic demonstrated that the machine was always held on a level keel, even when the mechanic walked well out toward the ends of the planes at a time when the pilot was standing and holding his hands above his head. The device maintains both the longitudinal and transverse stability and if the aeroplane drops below a certain speed it volplanes automatically. Manual control can supplant automatic at any moment the pilot wishes. Four small gyroscopes (two pairs) are used to control valves regulating the operation of the ailerons and elevator, which is accomplished by means of compressed air. The whole apparatus weighs but 46¼ pounds. There were a number of difficulties in applying the gyroscope to the aeroplane for this purpose. These were successfully overcome by Mr. Elmer A. Sperry, the inventor, who is the first to so apply the gyroscope that no matter in which direction an aeroplane tends to tip, it will be kept from tipping by proper instantaneous setting of the controls.

A full description of the Paul Schmitt biplane was published in the SCIENTIFIC AMERICAN of July 18th. The variable incidence of the planes of this machine in flight make it possible to carry big loads and to prevent stalling, as the machine is controlled by changing the angle of the wings rather than by means of the regular control surfaces. This biplane has made some extraordinary speed and height records carrying five or six passengers. It broke twenty-seven world's records in one day and made eleven new ones. It is able to start and alight in a space of 300 feet.

It is probable that had there not been so much red tape in accepting entries, A. Leo Stevens would have won a substantial prize with his safety pack—a parachute device that is worn like a knapsack. Mr. Stevens, who is a member of the Aero Club of France, cabled his entry and entrance fee, but the entry was thrown out on the pretext that the money was not received in time. This action of the Union has deprived the French government of a valuable apparatus for saving the lives of its aviators. Red tape in our War Department is similarly affecting our aviators, although the Sperry stabilizer is being fitted to several naval aeroplanes.

In the August issue of *Aircraft* we find the following interesting story of the French trials:

The Sperry gyroscope, in its application to the flying machine, is another example of the remarkable speed of the development of some modern epochal invention. Two years ago, Mr. Elmer A. Sperry fitted a Curtiss aeroplane with his device, and experiments in stabilizing were then undertaken. Careful testing continued all winter at San Diego, under the eye of Glenn H. Curtiss and the officers of the Aviation Corps of the United States Army. Many improvements were made, and the progress was steadily continued for many months at Hammondsport.

Full details have now been received of the signal triumph of this wonderful product of American ingenuity in France, where, at a safety contest the award of $10,000 offered by the French War Department was won by the aeroplane fitted with the Sperry stabilizer. The contest, extending over two hours, was held on the Seine between Bezons and Argentine. Lawrence D. Sperry, son of the inventor, piloted the winning machine, assisted by a mechanician. The control of the machine was perfect, young Sperry standing up during the flight with his arms folded, while the mechanician climbed to the end of the lower plane and back.

M. Rene Quinton, the president of the National Aerial League of France, who states that the invention is being hailed by European experts as one of the most important contributions ever made to the science of aviation, gives a graphic account of a flight which he took with young Sperry. He says: "Imagine the aeroplane in flight. At a given moment the passenger rises, leaves his seat, and climbing out onto a wing calmly walks here and there, as the fancy takes him. At the same time, the pilot rises and holds his two arms above his head, in order to prove that he is not touching any of the mechanism. The aeroplane, abandoned and apparently thrown out of equilibrium, keeps on its even way at a speed of 50 miles an hour. We were in the very teeth of the heavy wind, but, strange to say, it had no effect upon the working of the apparatus. There was no rolling, no pitching. One might have thought oneself in an ordinary machine in absolutely calm weather. At a height of 150 meters, Mr. Sperry made two demonstrations of automatic volplaning. It is well known that in order to execute a volplane, the aviator must allow his aeroplane to dive abruptly so as to regain the speed that the stopping of the motor has caused him to lose. Would the Sperry apparatus be able to accomplish this difficult maneuver without the aid of man? In order to prove to me that it would, Mr. Sperry stopped his motor, then raised his hands once more to show that he was not touching the levers. Nothing happened for five or six seconds; the machine appeared to have stopped. Then, suddenly it plunged head down, like a dolphin, in a dive that was as graceful as it was impressive. We rose again, and Mr. Sperry had a new experience for me—a glide with one wing so sharply inclined that it seemed incredible that the apparatus could be working. We leaned over toward the horizon at at angle of 45 degrees. The pilot did not touch the controls. The machine governed itself, and even in this abnormal position, while literally buffeted by the wind, it navigated in absolute safety. The Sperry apparatus consists of four little gyroscopes that never fail to bring back the machine to a horizontal plane. The entire outfit weighs about forty pounds. The tests I have described indicate remarkable progress toward the solution of one of the most wonderful problems of the age, that of safe human flight. They prove that we now have the means of enabling the aeroplane to control itself, whether it is rising, flying straight ahead, descending or battling with the wind, and that this marvelous machine, hitherto restricted to the few, is soon to be made available to the whole human race; the peer in speed of the rapidest automobile, and absolutely as easy and as safe to operate."

The Sperry machine is small and compact, 14 inches high by 14 inches wide, and it can be applied to any aeroplane without change in design. In the appended illustration the complete apparatus is shown, mounted on the bow of a flying-boat, the spray hood having been removed for the purpose of taking the picture. The gyroscopic element is plainly shown under the light semi-circular bow which actuates the longitudinal servo-motor, the lateral servo-motor being seen just behind the top of the bow. The anemometer which actuates the automatic volplane mechanism is seen on the upper left.

For the additional guidance of the observers attending the French demonstration, a special programme was given out, which is most suggestive as indicating the thoroughness of the tests prepared. The programme sets forth:

In demonstrating the Sperry-Curtiss stabilizer the pilot will carry out this programme as far as possible.

(A) An explanation of the aeroplane used and the method of operation of the apparatus.

You are asked to especially observe the following:

1. The aeroplane used is the well-known Curtiss flying boat with the controls arranged on the usual Curtiss system operated solely by hands and shoulders. The feet are not used in any way in controlling the machine. The aeroplane has the normal Curtiss relation between the gravity, thrusts and buoyancy centers, and has no inherent stability.

2. The servo-motors of the automatic stabilizer are directly connected with the same controls that the aviator would ordinarily operate by hand.

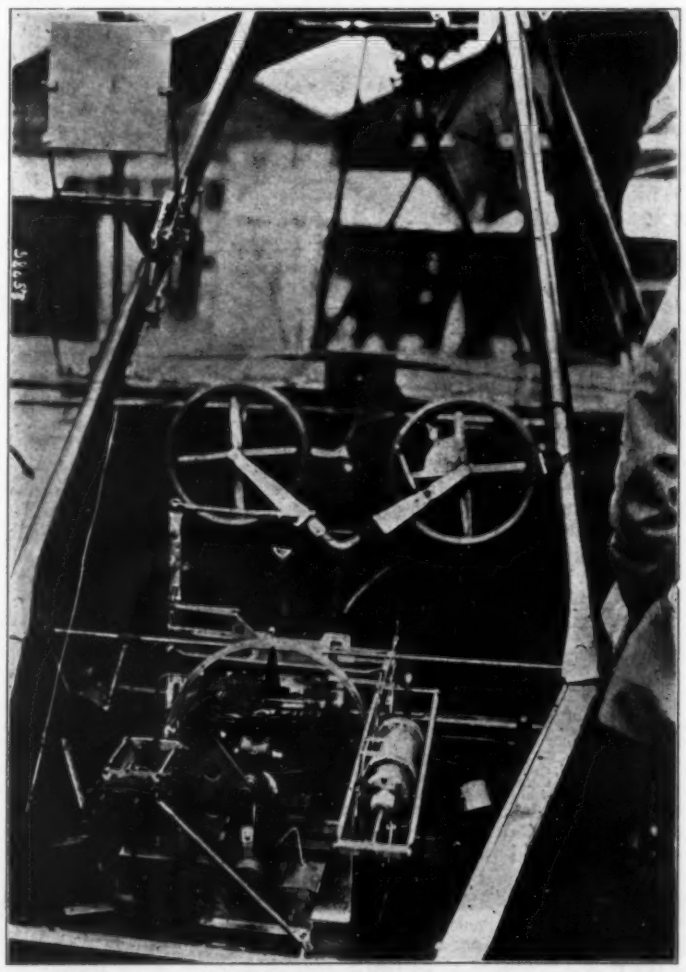
3. A simple foot treadle can instantly throw both the lateral and the longitudinal controls into or out of operation at will. When the automatic control is thrown into operation, it moves the controls when there is any relative movement between the aeroplane and the gyroscopic base-line. This will be demonstrated by moving the gyroscopic base-line, the gyros being stopped in this case. When the machine is in flight, the rotation of the gyros holds the structure in which they are mounted truly horizontal regardless of all movements of the machine.

4. When the automatic stabilizer is in operation, the controls are held with perfect rigidity, and the pilot cannot use them even if he wishes.

5. When the automatic stabilizer is in operation, the pilot uses the small lever to the left for controlling the aeroplane longitudinally, and the small pendant lever on the steering wheel for controlling the aeroplane laterally. He is entirely relieved of the task of stabilizing the aeroplane, and uses these levers only for directing its flight.

(B) Demonstration of the action of the automatic stabilizer when an upsetting force is applied in flight.

6. The passenger making this flight weighs about eighty kilogrammes.



The Sperry gyro stabilizer mounted in the bow of a flying boat.

7. The machine will rise from the water in the usual manner, and fly under automatic control.

8. Automatic lateral control will first be demonstrated, as follows: The passenger will leave his seat and climb out on the wing to one side for a distance of between one and one half and two meters from the center of gravity of the plane. While this is being done the machine will be under automatic control.

Observe that:

(*a*) The upsetting couple applied by the passenger is between one hundred and twenty and one hundred and fifty meter kilogrammes.

(*b*) The pilot is showing that the machine is under automatic control by moving out of his controlling seat and holding his hands above his head.

(*c*) The aeroplane is held perfectly level by the operation of the automatic control.

(*d*) As the passenger moves out on the plane, the angle at which the ailerons meet with the air gradually increases to automatically compensate for the upsetting couple. As the passenger returns toward the center, the ailerons gradually return to their normal position.

9. Demonstration of automatic longitudinal control. The passenger will leave his seat, climb up on the lower plane, and go backward, approaching the propeller as closely as possible.

The upsetting couple applied in this case is about eighty meter kilogrammes.

The same points should be observed as given under No. 8, i. e., that the machine is entirely under automatic control, that the longitudinal inclination of the aeroplane does not change, and that the rudder is now compensating for the upsetting couple.

(C) Demonstration to observers who will make flights as passengers in the demonstrating machine.

The passenger is asked especially to observe the following points:

10. After gaining speed on the water, the automatic stabilizer will be thrown in, and the aeroplane will rise from the water under complete automatic control. In rising from the water, and in controlling the angle or climb of the aeroplane, the pilot uses the small lever to the left.

11. The aeroplane flies smoothly with almost complete absence of the so-called "bumps."

12. The pilot is relieved from all work of stabilizing the machine, and has only to direct its flight, which task becomes simpler and easier than steering a motor car. The pilot will from time to time place his hands on the steering wheel for the purpose of keeping the machine on a straight course of flight. When the pilot touches the steering wheel while the automatic stabilizer is in operation, he cannot in any way assist the apparatus in stabilizing the machine, because the controls are rigidly held by the servo-motors.

13. The gyroscopic base-line, i. e., the structure in which the gyroscopes are held, constantly maintains the horizontal plane. The graduated circles on this device act as an accurate clinometer, constantly indicating the inclination of the machine laterally and longitudinally.

14. The gyroscopic base-line is causing the controls to ailerons and rudders to make very small movements. These movements are instantly counteracting each disturbing effect simultaneously with its occurrence.

15. By operating the foot-treadle the pilot can instantly throw out the automatic control and assume hand control. Note the difference in regard to smoothness of flight when the automatic control is thrown out.

16. When the pilot throttles his engine, and in that way approaches too closely the critical speed necessary in order to sustain the aeroplane, the automatic air velocity device operates to volplane the machine to an angle of about twenty degrees.

17. When the automatic air velocity device has volplaned the machine, the pilot cannot regain automatic longitudinal control until the volplane has brought the speed of the machine back to normal.

18. When the aeroplane turns, automatic control continues to operate, although the pilot can use any angle of banking he wishes.

19. When the speed of the engine is reduced, all parts function as before. The automatic stabilizing device is independent of the engine for a time sufficient to enable the pilot to make a landing or to restart the engine in case the latter accidentally stops.

20. The pilot alights on the water with the aeroplane under full automatic control.

Recording Moonlight and Night Cloudiness

By Alexander McAdie

ONE looks in vain through text-books on meteorology, official circulars of instruction, observers' handbooks, etc., for information regarding records of moonlight and night cloudiness. In fact, cloudiness during the dark hours, or practically half of the time, is discreetly let alone by professional meteorologists. If recorded at all, the data are in abbreviated form, and are generally based upon hearsay, such as statements of night watchmen, milkmen, and others. Such data are, of course, of doubtful value. And yet many a case in criminal and civil courts requires evidence of a positive character regarding cloudiness at night, and particularly the illumination due to moonlight.

For getting a record of night cloudiness, there has been used at Blue Hill Observatory for many years a Polestar recorder. This is a photographic record of a star trail, in this case Ursa Minor, devised in 1885 by Prof. E. C. Pickering. In 1904 the instrument was modified by Ferguson, and a record for two weeks may be obtained on one film; the instrument is practically automatic. The cost is not large, and there would seem to be no good reason why the instrument should not be generally used. If the night is clear, in the northern portion of the sky, the trail made by the star is continuous. For example, in Fig. 1 the record for the night of April 22nd-23rd shows that the sky was entirely clear, whereas the record for April 23rd-24th shows cloudiness at intervals during the early portion of the night, complete cloudiness for an hour at midnight, and clear weather thereafter. Similarly, the night of April 24th-25th was more or less cloudy. In this latitude the instrument gives a fair record of night cloudiness for the entire sky.

For recording cloudiness during the day hours various sunshine instruments are used, some thermometric (therefore responsive to heat, and recording too much if the temperature continues high after sunset, and too little if the temperature falls rapidly during the day); and the photometric based chiefly on the discoloration of some sensitized paper. At Blue Hill there has been in constant use the well-known Campbell-Stokes sunshine recorder, which consists essentially of a glass sphere focusing the sun's rays and burning a record upon a strip of prepared paper. It occurred to the writer that this instrument might also be used to obtain a record of moonlight by placing a strip of photographic paper, not over-sensitive, in the metallic frame, protecting it as much as possible from extraneous light and from the weather. Some very good records have been thus obtained, and it is quite easy to thus ascertain the intensity of the illumination due to the moon. An interesting record (Fig. 2) is that of March 11th-12th, during a lunar eclipse. The moon entered the penumbra at 8:41 P. M. and entered the shadow at 9:42. The middle of the eclipse was at 11:13 P. M., the moon leaving the shadow at 12:44 A. M. and the penumbra at 1:45 A. M. The night was beautifully clear. On the record (Fig. 2) it will be seen that the light gradually became dim, disappearing about 11 and reappearing after midnight. A record (Fig. 3) for the succeeding night shows that there was moonlight, with intervals of cloudiness, until 10:50 P. M., after which the moon was obscured. It is not known that any previous records of this character have been made.

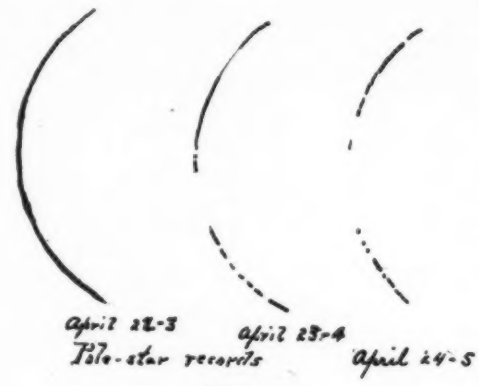


Fig. 1.

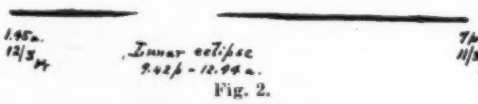


Fig. 2.

Fig. 3.

The whole subject of cloudiness, or perhaps it would be better to say obscuration by clouds, is in a most unsatisfactory state. At most observatories it is considered sufficient to enter the state of the sky twice in twenty-four hours. In this country the hours are 8 A. M. and 8 P. M., but such a practice certainly does not afford a fair basis for estimating the relative cloudiness of the place. On the other hand, a systematic survey of the cloud forms requires endless time and patience. One of the most remarkable cloud records is that of Mr. Spencer C. Russell at Epsom, Surrey, who maintained an hourly record for eight years. During this period he accumulated nearly 100,000 individual records. He has published the results of monthly and hourly cloud-form frequencies in the *Quarterly Journal* of the Royal Meteorological Society, October, 1913. He groups the clouds into four main classes: 1, Upper clouds, including all cirrus type; 2, intermediate clouds, including most of the cumulus and stratus formations; 3, lower clouds, including fog; and 4, diurnal ascending current formations. Curves showing hourly and monthly frequencies are given at some length. Nor is the matter of cloudless periods omitted, as is so often done in cloud discussions. One remarkable period of cloudlessness is reported as occurring in 1909, when from 6 P. M. April 4th until 5 P. M. April 11th—167 hours—no clouds were visible. The duration of cloudlessness varies greatly with locality. On the Atlantic seaboard periods exceeding three days are rare; but in the far western part of the United States, especially in California and Arizona, periods of a month or longer without cloudiness are not infrequent. Langley in his experiments at Mount Whitney speaks of the weeks which passed without a cloud in the sky; and it is common experience in the high Sierras during July, August, and September to find the sky entirely cloudless, week after week. On the other hand, in certain seasons thunderstorms may be frequent and afternoon cloudiness marked. The writer once had the privilege of spending a week on the summit of Mount Whitney at the end of August, and more than half the time it was cloudy.

While it is important, for many reasons, that cloudiness should be reported with some detail, still the records should be as compact as possible. A good illustration of a handy form of record is shown in Fig. 4. This was made at San Francisco some years ago, under the writer's direction, for a lighting company. A similar record for the succeeding month showed an entirely different distribution of cloudiness; in fact, the month was so cloudy that the demand for light was double that of the preceding month. At Blue Hill we have adopted a method of charting the cloudiness for each hour throughout the year on a sheet of millimeter paper 24 centimeters wide and 73 centimeters long. The record of cloudiness at Blue Hill is probably more complete than at any other point in the United States.

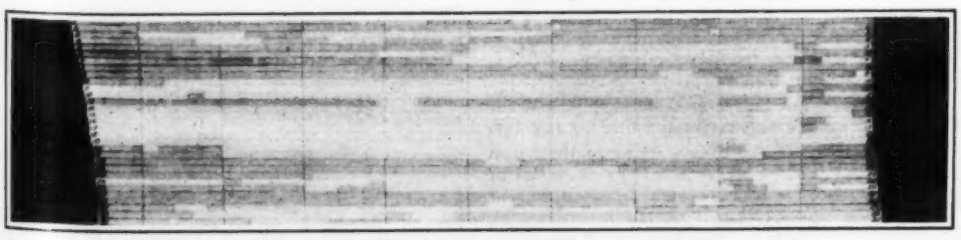


Fig. 4.—Record of cloudiness covering one month.

Determination of Ammonia in Illuminating Gas

FOUR common forms of apparatus for the determination of ammonia in gas, and a new form designed on the principle of the Cumming wash bottle were recently tested at the Bureau of Standards, at Washton, by J. D. Edwards, laboratory assistant, and the results show that the amount of ammonia in a gas can be determined with sufficient accuracy for official or commercial testing with any of the five forms. The advantages and disadvantages of each form as well as precautions to be observed in operations are pointed out in the text.

The subject is fully treated and described, with illustrations, in No. 34 of the technological papers published by the Bureau of Standards, and in summing up it is recommended that the ammonia be determined by absorption in sulphuric acid with subsequent titration of the excess acid and not by passing gas through the apparatus until a color change is shown by the indicator. It is satisfactory, however, when it is only desired to know whether the ammonia content is above or below a certain limit, to pass a predetermined volume of gas and note whether the acid has been completely neutralized or not.

Sodium alizarinsulphonate, cochineal, and paranitrophenol have been found to be satisfactory indicators. The use of a N/50 solution of sulphuric acid as an absorbing agent is recommended, although the strength may be varied to meet different conditions.

The errors due to incomplete washing and the use of glass beads are discussed, and means of eliminating their effect are given. See B. of S. Circular No. 48.

The Flying Machine from an Engineering Standpoint—II*

A Review of Recent Progress

By Frederick William Lanchester, M. Inst., C. E.

Continued from SCIENTIFIC AMERICAN SUPPLEMENT No. 2014, Page 91, August 8, 1914

REFERRING to Fig. 7a, it may be observed that the character of the pitching-moment curve depends primarily upon the form of the aerofoil, the position of the center of gravity, and the effective area of the tail-member. By altering the angle of the tail-plane (or by altering its effective angle by moving the flap known as the elevator) the datum line of Fig. 7a is in effect raised or lowered, but the form of the curve itself is not materially changed. It is evident, therefore, that a given machine may be catastrophically stable within certain limits of the adjustment of its elevator; that is to say, referring to Fig. 7a, it will be seen that the datum line may either cut the curve once or three times; the range of adjustment of the elevator that results in cutting the curve once leaves the machine catastrophically stable; but when the elevator is adjusted so that the datum line cuts the curve three times the machine is catastrophically unstable. In such a case as that shown by the dotted datum line in Fig. 7a, in which the machine is catastrophically stable, the form of the pitching-moment curve is still open to objection. Not only is it always possible for the pilot to bring about catastrophic instability by an otherwise well-intentioned movement of his elevator, but the restoring couple for pitching beyond a small amplitude ceases to follow even approximately the straight-line law, a fact that inevitably imperils the flight-path stability. Even when, as illustrated in Fig. 8, the pitching-moment curve *bb* never passes the horizontal, and so catastrophic instability is no longer to be feared, the conditions are not satisfactory, since there may be a considerable change of attitude of the machine without giving rise to any commensurate restoring couple.

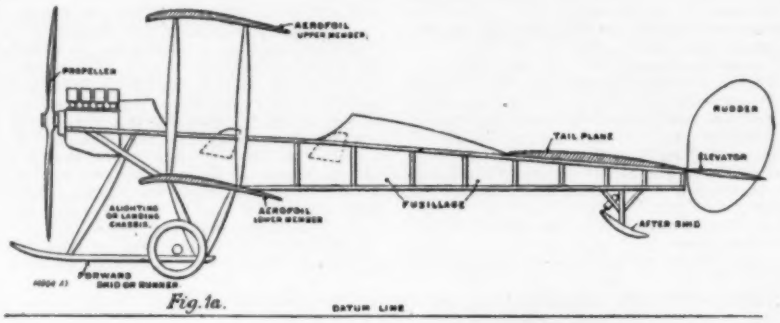
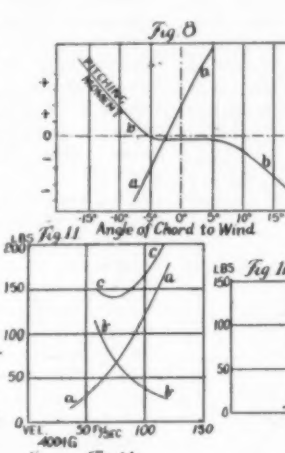
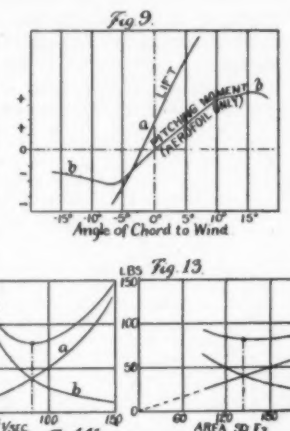
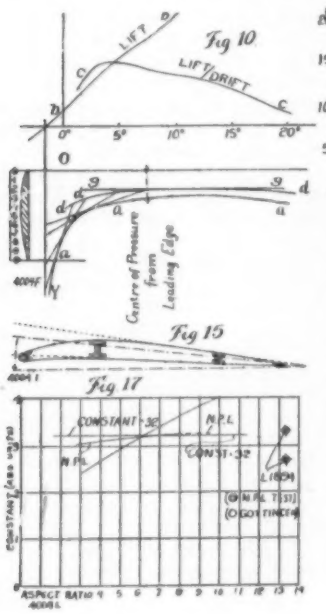
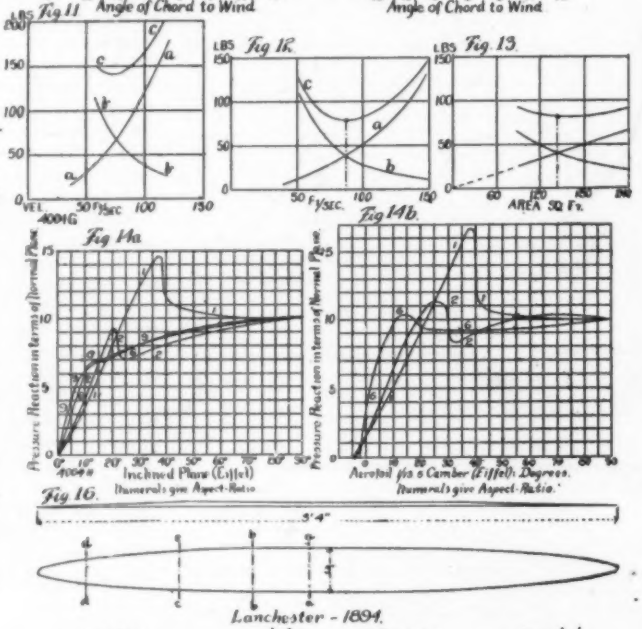


Fig. 1a.









In order definitely to make sure of a satisfactory pitching-moment curve for the complete machine, the pitching-moment curve of the aerofoil alone should at no point exhibit an inverse trend. To achieve this it is necessary to bring the center of gravity appreciably in front of the most forward position of the center of pressure of the aerofoil, so that the tail-plane will under all conditions carry a slight negative load. Taking it as a basis that at the worst point the pitching-moment curve for the aerofoil alone shall be horizontal (the form of curve shown in Fig. 8), the geometrical construction given in Fig. 10 may be employed to give a suitable location to the center of gravity; here the locus of the center of pressure (as experimentally determined) is given by the line *aaa*, the pressure-reaction curve is shown by the line *bbb*, the dynamic zero being on the line *OY*. A number of tangents to the pitching-moment curve are drawn at random from points on the axis *OY*, and are produced a distance equal to their own length beyond the point of contact, the extremities of these tangents defining a curve *ddd*. Draw *gg* tangent to *ddd*, then the center of gravity should be situated on, or forward of, the line *gg*. The location of the center of gravity on this line gives a pitching-moment curve for the aerofoil alone, whose point of inflection is horizontal (as in Fig. 8). If we assume the machine flown at a normal speed corresponding to the maximum lift/drift ratio of the aerofoil (curve *cc*), the center of gravity in this particular case is one eighth of the chord length in advance of the center of pressure. Assuming the tail length equal to three times the chord (as in the "B.E. 2" type of the Royal Air-Craft Factory, whose outline elevation forms Fig. 1*a*) this is equivalent to a negative load on the tail equal to 0.04 (4 per cent) of the weight of the machine.[9] A machine so ballasted may be regarded as absolutely secure from catastrophic instability, and as having a pitching-moment curve of an adequate character.

In connection with the present subject it is worthy of remark that in a well-designed aerofoil the most forward position of the center of pressure is never far removed from the point of maximum lift/drift ratio;[10] this fact is of importance, inasmuch as it permits a considerable range of movement round about the attitude of normal flight without introducing grave irregularities in the pitching-moment curve. Were it not for this the required conditions might frequently be far more difficult of fulfilment than is actually the case.

3. *The Laws of Resistance.*—Having established the general character of the airway, or track on which the flying machine is sustained, we pass directly to the consideration of the law of resistance, as determining the coefficient of traction, on which depends the power expenditure. It is customary, and it is correct, to regard the resistance encountered by a machine in flight as made up of two parts: first, the direct resistance, which varies approximately[11] as V^2, namely, that form of resistance common to flying machines, dirigibles, motorcars, ships, etc.; in other words, the ordinary resistance experienced by any vessel or body in its passage through a fluid; and, secondly, the flight resistance proper, which follows an entirely different *régime*.

So far as the pilot or aviator himself is concerned, all the direct resistances may be regarded as of the same kind and grouped together, namely, the sum of the eddy-making and skin-frictional resistances due to the fuselage, the alighting chassis, and the various struts, stays, and spars, whether belonging to the body of the machine or aerofoil; also the engine resistance (if exposed), the radiator, and the frictionally exposed surfaces of the rudders, fins (vertical surface), and of the aerofoil itself. Resistance from all these causes varies approximately as V^2, and so can be represented by an equivalent normal plane, and this equivalent normal plane is one of the resistance constants of any given machine; it may be represented by a graph as, Fig. 11—a portion of a parabola—covering the range of speed of which the machine is capable.

From the point of view of the pilot, the aerodynamic resistance *bb*, which goes to make up the total *cc* (Fig. 11), follows, within limits, the inverse square law,

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* The James Forrest lecture, delivered before the Institution of Civil Engineers on May 5th. Compare also the same author's paper on "Catastrophic Instability in Aeroplanes," SCIENTIFIC AMERICAN SUPPLEMENT, February 14th, 1914, p. 98.

[9] A similar conclusion was reached by the author some eight years ago, based on an entirely different method of investigation. For model experiment a negatively loaded tail was found to be advantageous; the figure 0.035 is given in "Aerial Flight," vol. II, p. 335. It is desirable to work with a less proportion of negative load from the point of view of keeping the resistance low; evidently the matter is one for compromise.

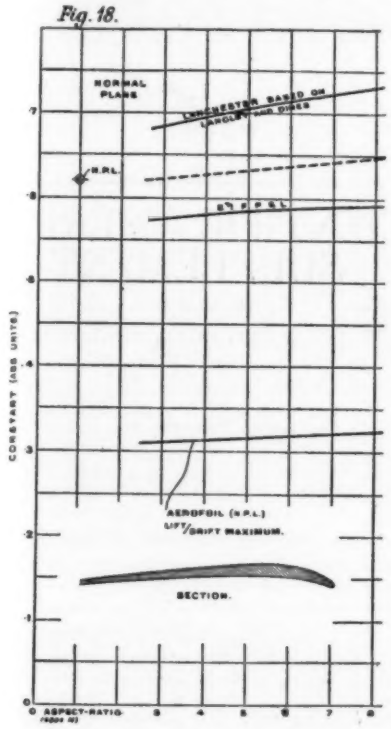
[10] This is not in the nature of a coincidence; a well-designed aerofoil at its attitude of least resistance meets and leaves the stream lines representing the relative air flow (in the region of its mid-section) conformably. Under these conditions small changes of attitude one way or the other do not cause any abrupt change in the aerodynamic system. Such expedients as flattening the extremities and giving a reflex curve to the trailing edge are also found to be of service.

[11] The V^2 law, it would appear, in no case exactly represents the actual facts; the departures from this law crop up in various and sometimes most unexpected directions. In the case of resistance due to skin-friction, sufficient data exist to enable the degree of departure from the law to be computed; in other cases, as for example, in the pressure reaction experienced by an inclined plane or aerofoil, departures of a different kind have been demonstrated, and are being gradually elucidated by experimental investigation. In spite of these shortcomings, the foundation the[illegible] of flight is to-day, and probably will continue to be, built on the V^2 law.

namely, varies as k/V^2, where k is a constant determined by the design of the aerofoil; there is a critical angle which defines the low velocity limit of this law, and at best the inverse square law is but an approximation; it is the correct law to assume for an undefined form of aerofoil, but every individual design has its own particular manner of variation, which must be ascertained by experiment. The experimental determinations for any aerofoil include, with the aerodynamic resistance, the skin-frictional, and a certain amount of other inseparable direct resistance, so that if experimental values are taken, these resistances should not be again included in the computation of the equivalent normal plane.

From the point of view of the designer, things wear a somewhat different aspect, and a sharp line has to be drawn between two different classes of direct resistance. In the first place, there is the body resistance, which is taken to include the resistance of all those parts, such as fuselage, alighting gear, etc., which is independent of the design of the aerofoil. In the second place, there is the direct aerofoil resistance, including the skin-friction and strut and stay resistances, which are variables depending upon the area and span, and otherwise upon the design of the aerofoil itself. The designer can, by sufficiently extending the aerofoil, reduce the aerodynamic resistance (as shown by Langley) to as low a value as he please, within the limit prescribed by the question of the added weight; but this reduction in the aerodynamic resistance is accompanied by an increase of skin-frictional and other direct aerofoil resistances, so that for any given machine and designed velocity

Fig. 18.



there is an extent of aerofoil beyond which it does not pay to go; there is definitely a design of least resistance.

I have shown that, treating the matter from the broad standpoint of general theory, the condition of least resistance is reached when the aerodynamic and direct resistance of the aerofoil are equal to one another.[12] This is illustrated by Fig. 12, in which (as in Fig. 11) *aa* represents the graph of the direct resistance ($R \propto V^2$), and *bb* that of aerodynamic resistance ($R \propto 1/V^2$), and *cc* is the total (ordinates = resistance,

TABLE IV.—*Values of β (Angle of Trail) for Least Resistance.*

Aspect Ratio.	$\epsilon = 0.20$	$\epsilon = 0.015$.	$\epsilon = 0.010$.
	deg.	deg.	deg.
3	0.189 = 10.8	0.163 = 9.3	0.133 = 7.6
4	0.196 = 11.2	0.169 = 9.7	0.138 = 7.9
5	0.202 = 11.6	0.174 = 10.0	0.142 = 8.1
6	0.206 = 11.8	0.178 = 10.2	0.145 = 8.3
7	0.212 = 12.15	0.183 = 10.5	0.149 = 8.5
8	0.218 = 12.5	0.189 = 10.8	0.145 = 8.8

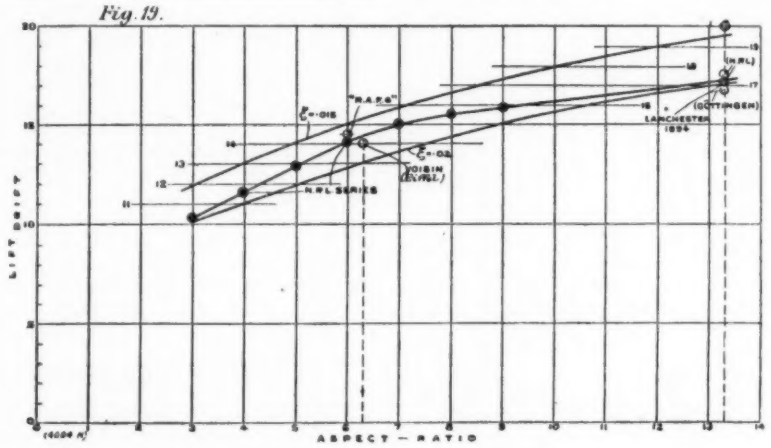
abscissæ = velocity). In Fig. 13 a similar result is shown in which the plotting is given for constant velocity (abscissæ = area), as representing more literally the problem as presented to the designer.

The general theory on which the foregoing result is based depends upon and is subject to the limitations of the $1/V^2$ law of aerodynamic resistance. This law corresponds to the straight-line law as correlating pressure and angle, and is a close approximation between useful limits, but breaks down at a certain critical maximum angle (depending mainly upon the aspect ratio), as shown in the examples given in Figs. 14*a* and 14*b*. The square plane follows a straight-line law up to about 30 degrees, in the plane of aspect ratio = 6; the limit is about 12 degrees, the breakdown of the law at these limiting angles puts a very definite limit to flying at low speed.

TABLE V.—*Pterygoid Aerofoil.*
Load (pounds) per Square Foot for Least Resistance.

	Flight Velocity.	Values of Aspect Ratio.					
	Feet per Second.	3	4	5	6	7	8
$\epsilon = 0.020$	5	0.017	0.018	0.020	0.022	0.023	0.025
	10	0.068	0.075	0.082	0.089	0.094	0.101
	15	0.152	0.169	0.186	0.200	0.213	0.228
	20	0.270	0.300	0.330	0.355	0.379	0.405
	25	0.390	0.433	0.475	0.511	0.545	0.582
	30	0.610	0.676	0.743	0.800	0.852	0.911
	35	0.830	0.920	1.01	1.08	1.16	1.24
	40	1.08	1.20	1.32	1.42	1.51	1.62
	50	1.69	1.88	2.06	2.22	2.37	2.53
	60	2.44	2.70	2.97	3.20	3.40	3.64
	70	3.32	3.68	4.05	4.35	4.64	4.96
	80	4.33	4.81	5.30	5.70	6.07	6.47
$\epsilon = 0.010$	5	0.012	0.013	0.014	0.015	0.016	0.018
	10	0.047	0.053	0.058	0.063	0.066	0.071
	15	0.107	0.119	0.131	0.142	0.150	0.161
	20	0.190	0.211	0.234	0.253	0.267	0.287
	25	0.298	0.331	0.366	0.396	0.418	0.450
	30	0.427	0.475	0.526	0.570	0.601	0.645
	35	0.582	0.647	0.717	0.777	0.820	0.880
	40	0.760	0.845	0.935	1.01	1.07	1.15
	50	1.18	1.32	1.46	1.58	1.67	1.79
	60	1.71	1.90	2.10	2.28	2.30	2.58
	70	2.32	2.58	2.86	3.10	3.27	3.51
	80	3.04	3.38	3.73	4.05	4.27	4.59

Fig. 19.



I have demonstrated that the condition of least resistance implies, for an aerofoil of any given aspect ratio, a definite value of the angle of trail,[13] β, Fig. 15; the chord angle, except where a plane lamina is used, is an accidental quantity, and not; as frequently supposed, one of fundamental importance; calculated values of trail-angle β for least resistance are given in Table IV. Thus any aerofoil properly designed for least resistance for any given velocity of flight will be correctly designed for every other velocity provided that its load per unit area be varied as the square of the flight velocity.

It thus becomes possible to prepare tables of mean-pressure values proper to least resistance for different flight velocities and different values of aspect ratio (Table V). Tables IV and V are reproduced from my "Aerial Flight," vol. i, pages 261, 262, and 271, the variable factors in addition to the flight speed being the aspect ratio, which is here shown as tabulated for values from 3 to 8, and the coefficient of skin friction, values of which are taken from 0.01 to 0.02 double-surface coefficient. These values for skin friction are on the high side, but as an actual fact the values given do fairly represent the total direct resistance that in practice depends upon the area of the foil, and which requires to be included in the useful application of the theory; the higher values, generally speaking, represent more closely biplane conditions, and the lower values are more applicable in the case of the monoplane.

It would appear from recent experiment that my conclusions, as given in Tables IV and V, though in the main correct, require revision; at least in a quantitative sense. Thus plotting values of the pressure constant, as derived from Table V, for different values of aspect ratio, and as determined for the condition of least resistance (maximum lift/drift) by the National Physical Laboratory, Fig. 17, we find the two in perfect agreement for aspect ratio = 6; we also find that both graphs slope in the same direction, namely, they give a higher pressure constant as appropriate to higher aspect ratio; we do not, however, find justification for the extent of the difference as given in my table; the National Physical Laboratory curve gives the effect as very slight indeed—in fact, almost negligible; the pressure constant for the aerofoil tested might be assumed as 0.32 for all values of aspect ratio without serious error.[14]

In Fig. 18, the National Physical Laboratory curve from Fig. 17 has been plotted for comparison with the curve of the normal plane. It is well known that the pressure constant of the normal plane is greater for planes of elongate form; the normal plane curves given in Fig. 18 are based on the determinations of Langley and Dines, as given in "Aerial Flight" (the upper curve); and the more recent determinations of Mr. Eiffel, the values according to this authority being very much lower. On the left, on the line aspect ratio = 1, we have the value for the square plane as determined by the National Physical Laboratory, and a curve is shown (dotted) directed toward this point as being the nearest we can at present do toward a representation of the truth.

The relation of the normal plane curve to the National Physical Laboratory curve aforesaid is most suggestive; it happens that the values of the constants are almost exactly in the relation of two to one; this is probably a mere coincidence; a more important fact is that the increase of the pressure constant of least resistance (touching changes of aspect ratio) for the aerofoil is almost exactly proportional to the ordinary pressure increase in the case of variations of proportion in the normal plane. This suggests that the increase in the two cases is due to the same primary cause; also that the coefficient of camber proper to least resistance is a quantity independent of the aspect ratio. If this should turn out to be the case, the reduction of the resistance for aerofoils of high aspect ratio may be regarded as due entirely to the fact that, where the cyclic component is stronger, the dip of the leading edge can be increased at the expense of that of the trail; that is to say, the chord angle may be diminished with higher aspect ratio, and with it the trail angle will be also diminished. This is contrary to the tabulated results of Table IV; if true, it must lead to the reconsideration of some of the assumptions on which I based my theory, or at least in the revision of some of the values of my constants.

In spite of the evidence, it is by no means certain that the matter is quite as simple as it appears. It is to be observed that any investigation to determine the effect of aspect ratio must of necessity involve a very complex experimental campaign, not merely a set of determinations with some half dozen or so models sawn off to length from a piece of Blériot or de Havilland "molding"; this is exactly what was done in the experi-

[12] "Aerial Flight," vol. i, ch. vii.

[13] It is not easy to define the angle of trail of an aerofoil when the section is one of considerable body; clearly it is something intermediate between the upper and under surfaces, probably more nearly approximating to the former, as shown by the dotted line. Fig. 15.

[14] The series of observations from which the curve (*NPL*) in Fig. 17 was plotted are those given in Advisory Committee Report, 1911-12, Memorandum 60, § vi, Plate III; the section of the form of aerofoil used is given in the report, and is reproduced in silhouette in Fig. 16. The value of the pressure constant (at maximum lift/drift) evidently varies considerably for different forms of section. Rejecting forms that may be considered bad on account of their low maximum, we find: In Report 72 (1912-13) the fourth, fifth, and sixth sections given in Fig. 1, constants 0.322, 0.334, and 0.334, respectively. In the same report, § ii, figures are given of the tests of four aerofoils varied as to bluntness of leading edge. The three best of these each had a constant approximately 0.4. In the same report an aerofoil corresponding in form to "R.A.F. 6" gave a value almost exactly 0.3.

ments forming the basis of the plotting given in Fig. 17; any such method of investigation is liable to prove delusive."

In the first place each aspect ratio should be explored by a number of determinations using aerofoils of varying camber; secondly, the aerofoil section must not be uniform from end to end, the section must be "graded," or, as it is sometimes expressed, the camber must "wash out" at the extremities. Beyond this not one series must be tried, but some dozen or more. The final "winner" for each aspect ratio is the aerofoil of greatest lift/drift.

In my opinion, in the present unsatisfactory state of things, it is best (so far as the pressure constant is concerned) to assume a uniform value for all values of aspect ratio, say that given as appropriate to aspect ratio = 6 in Table V. Whether we consider the National Physical Laboratory result as valid or not, the salient fact is that we have at present no sufficient evidence that there is any change in the pressure constant worth taking into account. Alternatively, we are not going far astray if we assume aerofoil pressures equal to half the pressure on the normal plane, as shown in Fig. 18.

The most important fact with which we are immediately concerned in connection with the theory of least resistance is that the total aerofoil resistance for least value is almost constant in respect of velocity; in other words, provided that we design for least resistance, we know our traction coefficient in advance; it is virtually a constant, just as though the problem were that of an automobile required to ascend a hill of known gradient —an analogy which comprehends the fact that there is the direct wind resistance or body resistance additional in both cases. This constant is only within control inasmuch as by careful design the effective value of the coefficient of skin friction ξ can be kept down, and a high aspect ratio adopted. Theoretical values of least gliding angle (that is to say, resistance coefficient), tabulated for values of ξ and aspect ratio, are given in Table VI." It is of some interest to inquire to what extent these results are in agreement with modern experiment.

TABLE VI.—*Least Gliding Angle* ($= \gamma_0$) (*Theoretical*).

R	$\xi = 0.025$.		$\xi = 0.02$.		$\xi = 0.015$.		$\xi = 0.010$.	
	deg.		deg.		deg.		deg.	
3	6.25	1 : 9.2	5.6	1 : 10.2	4.8	1 : 12.0	3.95	1 : 14.5
4	5.75	1 : 10.0	5.15	1 : 11.1	4.4	1 : 13.0	3.65	1 : 15.7
5	5.3	1 : 10.8	4.75	1 : 12.0	4.1	1 : 14.0	3.4	1 : 16.8
6	5.0	1 : 11.5	4.5	1 : 12.8	3.9	1 : 14.7	3.2	1 : 17.9
7	4.7	1 : 12.2	4.25	1 : 13.5	3.6	1 : 15.9	3.0	1 : 19.1
8	4.5	1 : 12.8	4.0	1 : 14.4	3.4	1 : 16.8	2.8	1 : 20.5
..	....	.....	....	.....	...	.....	....	.....
10	4.1	1 : 14.0	3.65	1 : 15.8	3.2	1 : 17.9	2.6	1 : 22.
..	....	.....	....	.....	...	.....	....	.....
12	3.8	1 : 15.0	3.42	1 : 16.8	3.0	1 : 19.0	2.4	1 : 23.9

I have collected experimental data from various sources; a series of aerofoils of Blériot section,[17] aspect ratios vary from 3 to 8. Determinations of Voisin wing by M. Eiffel, aspect ratio 6.3. Aerofoil "R.A.F. 6" (Royal Aircraft Factory), aspect ratio 6. Aerofoils

TABLE VII.

1	2	3	4	5	6
Aspect Ratio.	Type.	Determination by	Experimental.	Calculated $\xi = 0.02$.	Calculated $\xi = 0.015$.
3.0	Bleriot section	N. P. L.	10.1	10.2	012.
4.0	"	"	11.5	11.1	13.0
5.0	"	"	12.9	12.0	14.0
6.0	"	"	14.0	12.8	14.8
6.0	R. A. F. 6	"	14.5	....	....
6.3	Voisin	Eiffel	14.0	....	....
7.0	Bleriot section	N. P. L.	15.1	13.5	15.9
8.0	"	"	15.5	14.4	16.8
10.0	.....	.....	....	15.8	17.9
12.0	.....	.....	....	16.8	19.0
13.3	Author, 1894	N. P. L.*	17.1	....	....
		" *	17.6	....	....
		" †	20.0	....	....
		Göttingen‡	16.4	....	....
		" ‡	17.3	....	....

from my 1894 model, aspect ratio 13.3, Fig. 16, independent determinations by N.P.L. and Göttingen laboratories. The above are given in Table VII; columns 1, 2, and 3 give the aspect ratio, type, and authority respectively; column 4 gives the experimental determination, and my theoretical values are given in columns 5 and 6 for values of $\xi = 0.02$ and $\xi = 0.015$. Table VII is shown plotted in Fig. 19, the relation of aspect ratio to lift/drift being represented by curves drawn through the observed and calculated values.

It will be noted on referring to Table VII and Fig. 19 that the agreement is almost complete. The two cases of the Eiffel determination of the Voisin aerofoil and the "R.A.F. 6" aerofoil are shown as outlying points, not being fully in agreement with the main run of the remaining experimental determination; it will be noted, however, that the whole of the experimental values lie between the two adjacent theoretical curves given, and the general form of the experimental curve corresponds to the curves given by my equations. It is true that there is something in the nature of the hump on the experimental curve, the extremities of which corresponds to a double-surface coefficient of skin friction of 0.02, whereas the central part of the curve round about aspect ratio = 6 rises nearly to the upper curve. This peculiarity of angular character of the curve may be a real feature, but I am disposed to think that it is more probably due to the fact that a great deal more experimental work has been done in the region of the hump of the curve, and so more highly perfected forms have been available than for aspect ratios of greater or less value. It would appear probable that if equal diligence were displayed in designing and testing forms of other aspect ratios, the upper theoretical curve ($\xi = 0.015$) would be found to be very close to the truth; some confirmation of this is found in the fact that the best value for the "R.A.F. 6" aerofoil, a form that has been subject to considerable study both by the Royal Aircraft Factory and the National Physical Laboratory, lies considerably above the curve representing the run of other observations.

In the National Physical Laboratory report to me on the tests of my 1894 model, it is stated that if it had been found possible to employ a velocity of 50 foot-seconds instead of 30 foot-seconds, the figure obtained would probably have reached the neighborhood of 20. This value is also plotted as an outstanding point in Fig. 19.

Summarizing the position, it is clear that the tractive effort required to overcome flight resistance proper—namely, the aerofoil resistance—need not exceed 1 in 12 to 1 in 14, that is, 7 or 8 per cent, using an aspect ratio of about 6, and that values less than this are to-day actually reached in existing machines. It is, furthermore, apparent that if it is found practicable to employ really high aspect ratio, such as in my early flight models, there is every reason to suppose that a resistance coefficient as low as 6 per cent, or even 5 per cent, may prove to be attainable. This is the magnitude of the "constant gradient" of the motorcar analogy. We now pass to the consideration of body resistance.

(To be continued.)

[16] It is an old axiom that in conducting a scientific research only one condition (when possible) should be changed at a time. In trying to adhere to this rule too literally it is easy to mistake the shadow for the substance; in the present example, to vary the length of an aerofoil of constant section may appear superficially to be "changing one condition," but in reality it is nothing of the kind.

[16] From "Aerial Flight," vol. I, p. 202.

[17] Report of the Advisory Committee for Aeronautics, 1911-1912, p. 75.

* Velocity, 30 feet per second.

† Value at 50 feet per second (computed by National Physical Laboratory).

‡ Velocity not stated.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

The Use of Graphite in Steam Boilers

To the Editor of the SCIENTIFIC AMERICAN SUPPLEMENT:

On page 35 of your SCIENTIFIC AMERICAN SUPPLEMENT No. 2011, dated July 18th, 1914, there appears an article, entitled "Graphite Against Furring," wherein it is intimated that the use of graphite in steam boilers as a scale remedy originated in Germany. We beg to inform you that the United States Graphite Company discovered this new use for graphite and were the first to offer it for sale for this purpose. The idea of using graphite as a boiler scale remedy was first brought to our attention by one of the best sugar plants operating in Colorado which experienced a great deal of trouble in this direction, and in casting about for a dependable removing agent secured, through our Denver branch, some of the graphite which we mine in Mexico, and tried it with such excellent result that we then, on our own account, made a great many exhaustive tests in a number of power plants, inclusive of our own here in Saginaw, where the feed water is usually bad.

The results following this investigation were so remarkable, and finding Mexican graphite to be, of all graphites, the best physically adapted for this use, we commenced to exploit it in that field with very remarkable success. UNITED STATES GRAPHITE COMPANY.

Saginaw, Mich.

The Horsepower of a Cannon

A MODERN field gun firing a 15-pound shot with a muzzle velocity of 1,600 feet per second gives it an energy of $\frac{15}{2} + \frac{(1,600)^2}{32}$ foot pounds. If we assume that the time required is one hundredth of a second, the horsepower developed is

$$\frac{15}{2} \times \frac{(1,600)^2}{32} \times \frac{100}{33,000} = \frac{15 \times 256,000,000}{2 \times 32 \times 5,500} = 108,000 \text{ h.p.}$$

Ships' guns greatly exceed this, the shot weighing as much as 1,100 pounds, and having a muzzle velocity of 3,000 feet per second. If we assume, as before, that the shot takes one hundredth of a second to reach the muzzle (it probably takes rather longer), we have for the horsepower in this case:

$$\frac{1,100 \times 9,000,000 \times 100}{2 \times 32 \times 5,500} = 28,000,000 \text{ h.p.}$$

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